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Monterey, California

THESIS

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NAVAL TELECOMMUNICATIONS CENTER, MONTEREY, CALIFORNIA

by

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A MANAGEMENT ANALYSIS OF THE

NAVAL TELECOMMUNICATIONS CENTER, MONTEREY, CALIFORNIA

by

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ABSTRACT

A management analysis of the Naval Telecommunications Center, Monterey, was conducted to analyze the requirements placed on this center, as well as to determine how capable it was to perform these requirements. A computer simulation model was developed and used to quantify the message processing capabilities of the center under various historical conditions. Results showed that the various requirements placed on this center have been constantly increasing, without regard to the center's ability to handle them. The results also showed that at times the center's capabilities were limited by its machine capabilities, while at other times they were limited by the center's own internal message handling procedures.

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I. OBJECTIVE

The objective of this thesis is to make a management analysis of the U. S. Naval Telecommunications Center, Monterey, California. This thesis examines what requirements have been placed on the telecommunications center, how well it has been fulfilling its requirements, and how those requirements have been changed in the recent past.

To accomplish this goal, a study was performed to analyze the external environment within which the telecommunications center operates. This study explains why the telecommunications center exists, as well as what its role is as an integral part of the total Naval Communications Systems.

The internal environment was analyzed as well. The internal constraints and capabilities were examined to determine how well this telecommunications center responded to its changing external environment. A computer simulation model of the telecommunications center was developed to quantify its capabilities and define its limitations. This simulation technique is readily modified to adapt to the changing external and internal requirements and capabilities of the center.

As a result of examining these two facets of the Naval Telecommunications Center, Monterey, greater understanding is gained of some everyday problems and mistakes found in a communications system. This thesis will also show the value of simulation as a technique for analyzing a communications system.

II. BACKGROUND AND STATEMENT OF THE PROBLEM

A. THE MAN-MACHINE INTERFACE

The major problem in the U. S. Naval Telecommunications System is the man-machine interface. This is the part of the total communications system in which manual handling of message traffic (in this case, in the form of punched paper tapes and hard copy messages) is necessary for the interface between one piece of mechanical equipment and another to be accomplished. Machine capabilities are subject to numerous variations, most of which have been the subject of a considerable amount of research resulting in a high degree of accuracy in performance measurement. Performance measurement of human capabilities is an art rather than a science. Although much expense and effort has been expended in this field, there is no generally accepted criteria for predicting human performance. Therefore, in any field of endeavor where man and machine must work in harmony to accomplish a specific task, much is known about the performance of the machine, but the performance of the man is largely an unknown and unpredictable quantity.

The U. S. Navy has, for the most part, mastered the technical problems in the automated machine portion of the Naval Telecommunications System; but when the message gets into the hands of the man, the objectives of Naval Communications--reliability, accuracy, speed, and security--are jeopardized. The Navy is acutely aware of this problem and there are, at present, plans to automate message handling at many communications stations, both ashore and afloat, within the next ten years.

B. THE NAVAL COMMUNICATIONS AUTOMATION PROGRAM

The Naval Communications Automation Program is designed to achieve the objectives of Naval Communication by means of the application of

state of the art automatic data processing technology and procedures. The approach taken is to gradually automate all key nodal points of the Naval Communications System. This system uses optical character readers, high-speed reproduction and sorting devices, video display terminals, as well as direct-access computer interfaces, all under the control of a central processing unit.

1. Objectives

The objectives of automating these key nodal points are:

a. Increased Speed

To reduce the average time required to process incoming and outgoing messages. In order to meet the Joint Chiefs of Staff required writer-to-reader handling times, the automated system will process Flash precedence messages in less than two minutes, Operational Immediate in under five minutes, Priority in an average of thirty minutes, and Routine in an average of one hour. "This objective can only be met with complete automation."[1]

b. Increased Accuracy

To reduce the error rates to less than one per cent of the message traffic handled.

c. Increased Security

To reduce security violations to near zero.

d. Increased Reliability

To reduce mis-routed messages and non-delivered messages to less than one in ten million.

[1]Naval Communications Automation Program ADP Systems Review, FY 1973, p. 1, 1972.

2. Automation Ashore

At present, there are fourteen of the automated communications stations proposed, of which two are operational. A test bed site is operational at the Washington Navy Yard, and a second unit is operational at the Chief of Naval Operations' Communications Center (OPNAV TCC). Three others are in various stages of completion. The system called the Local Digital Message System and the Naval Communications Processing and Routing System (LDMX/NAVCOMPARS) located at OPNAV TCC has cost about five million dollars to date, with an annual operating cost of about two and one-half million dollars. Over its proposed life of eight years, it is anticipated that the elimination of manpower and material as a result of this automated installation will save the Navy approximately two million dollars. Similar figures are available for the other LDMX/NAVCOMPARS sites.

3. Automation Afloat

In addition to these shore automated communications centers, there has been some progress in automating communication centers afloat. The automated Message Processing and Distribution System (MPDS) is currently installed and operating aboard the USS OKLAHOMA CITY. It is also being installed aboard the two new CVAN's currently under construction, the USS EISENHOWER and the USS NIMITZ. Because the MPDS has not been proven to be cost-effective, the Chief of Naval Operations' Industrial Advisory Committee on Telecommunications (CIACT) has recommended that this program be held in abeyance.[2]

These expensive, central-processor controlled systems will never be cost-effective for a small telecommunications center.

[2]CIACT Action Group, Communications Automation, p. 6-6, 1972.

Until some time in the future when inexpensive computers are in use, some other methods must be developed to upgrade the capabilities of the man in the man-machine interface. The function of the man is message handling and this takes time. This thesis examines the effects of this message handling time on the capabilities of the Naval Telecommunications Center, Monterey.

C. MISSIONS OF INVOLVED ACTIVITIES

The primary mission of the Naval Telecommunications Center, Monterey, is to provide communications support for all Naval activities in the Monterey area. These activities include the U. S. Naval Postgraduate School, the Defense Management Systems Center, which is closely allied with the Naval Postgraduate School, and the Fleet Numerical Weather Central. The missions of the Naval Postgraduate School and the Defense Management Systems Center are primarily to educate military officers and civilian employees. The mission of the Fleet Numerical Weather Central is, "to provide, on an operational basis, numerical meteorological products and oceanographic products peculiar to the needs of the Department of the Navy; and to develop and test numerical techniques in meteorology and oceanography applicable to NAVWEASERVCOM analytical and forecasting problems."[3] To accomplish this mission, enormous amounts of data must be received, analyzed, and sent to and from numerous activities.

By far, the heaviest burden (in traffic volume) placed on the Naval Telecommunications Center, Monterey, is message support for the Fleet Numerical Weather Central. When one considers the message volume handled by the telecommunications center, it, in effect, acts as a subunit of the Fleet Numerical Weather Central.

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[3]Fleet Numerical Weather Central, Monterey, California, Background Information Folder, p. 6.

It handles those messages which cannot, for reasons which shall be delineated later, be sent through Fleet Numerical Weather Central's numerous other communications channels. In fact, five of the seventeen missions and functions of the Fleet Numerical Weather Central, as found in their Background Information Folder, deal with data communications. Some of the networks presently in use include a multi-drop system, several point-to-point systems, and a switched network. Modes of operation feature computer-to-computer links, computer-to-teletype links and various types of hand-carried operations.

D. FLEET NUMERICAL WEATHER CENTRAL'S COMMUNICATIONS

1. Input

In discussion of Fleet Numerical Weather Central's communications, its overall role must be discussed. To accomplish its mission (as previously stated) it must receive and analyze data. This data consists primarily of synoptic meteorological observations taken and reported in accordance with the procedure of the World Meteorological Organization, and oceanographic observations obtained from U. S. Navy ships and aircraft, as well as merchant ships, fishing boats, and oceanographic research vessels.

The primary source of meteorological data for Fleet Numerical Weather Central is the worldwide network of observation stations coordinated by the World Meteorological Organization. This collection system is known as the World Weather Watch. Reported data from the World Weather Watch reaches Fleet Numerical Weather Central through various routes.

a. The Automated Weather Network

The route through which the majority of meteorological data

is received is the U. S. Air Force Automated Weather Network. This is because the U. S. Air Force has been tasked to run the weather collection system for the Department of Defense. The Automated Weather Network collects weather data from all over the world and relays it through high-speed lines to the Automated Digital Weather Switch, the collection point for the entire network, located at Carswell Air Force Base, Texas. The Global Weather Center at Offutt Air Force Base in Nebraska is the control center for Air Force users of this data.

b. The Naval Environmental Data Network

Fleet Numerical Weather Central, Monterey, is the master station of the Navy user network, known as the Naval Environmental Data Network. Data required by the Naval Environmental Data Network is relayed from Carswell Air Force Base to Fleet Numerical Weather Central. All the Naval Environmental Data Network lines are leased commerical lines which are contracted and budgeted for by the Commander, Naval Communications Command, but managed by the Commander, Naval Weather Service Command.

Weather observations taken by U. S. Navy ships in accordance with NAVWEASERVCOMINST 3140.1A and NWP-16 are transmitted to prescribed regional Fleet Weather Centers for entry into the Naval Environmental Data Network. These same observations are also sent from the ships directly to Fleet Numerical Weather Central. Data obtained from meteorological satellites is collected by the Naval Environmental Satellite Center and is entered into the Naval Environmental Data Network by the Fleet Weather Facility, Suitland, Maryland.

For oceanographic data, the Naval Weather Service relies on all possible sources of data. Reports from U. S. Navy ships are taken in accordance with OCEANAVINST 3160.4 and 3160.9. These reports were

once sent directly from the ships to the prescribed regional Fleet Weather Center, and from there over the Naval Environmental Data Network to Fleet Numerical Weather Central. These messages are now sent directly from the ships to Fleet Numerical Weather Central. In addition, overseas Fleet Weather Centers collect oceanographic data from all available foreign sources and transmit this data to Fleet Numerical Weather Central. Many oceanographic reports are collected from fishing vessels by the Bureau of Commerical Fisheries Activity, La Jolla, California, and are then transmitted to Fleet Numerical Weather Central via the West Coast Tie Line.

2. Output

Once this data is received, it is processed and analyzed. The output consists of meteorological and oceanographic observed data, analyses and prognoses to all Naval Weather Service and other activities on the Naval Environmental Data Network, to fleet users via the Naval Environmental Data Network and Naval Communications Command facilities, and to Air Force users via the Automated Weather Network.

E. FLEET NUMERICAL WEATHER CENTRAL'S CIRCUITS

In order to fully understand the role of the Naval Telecommunica ions Center, Monterey, the communications circuits supporting Fleet Numerical Weather Central must be examined. (Refer to figures 1-3)

1. Automated Weather Network Circuits

As previously mentioned, the primary data source for Fleet Numerical Weather Central is the Air Force Automated Weather Network. Fleet Numerical Weather Central has two primary circuits and their backups connecting it to the Automated Weather Network. The first circuit connects the UNIVAC 1108 computer at Carswell Air Force Base by means of

NEDN MAINLINE CIRCUITRY

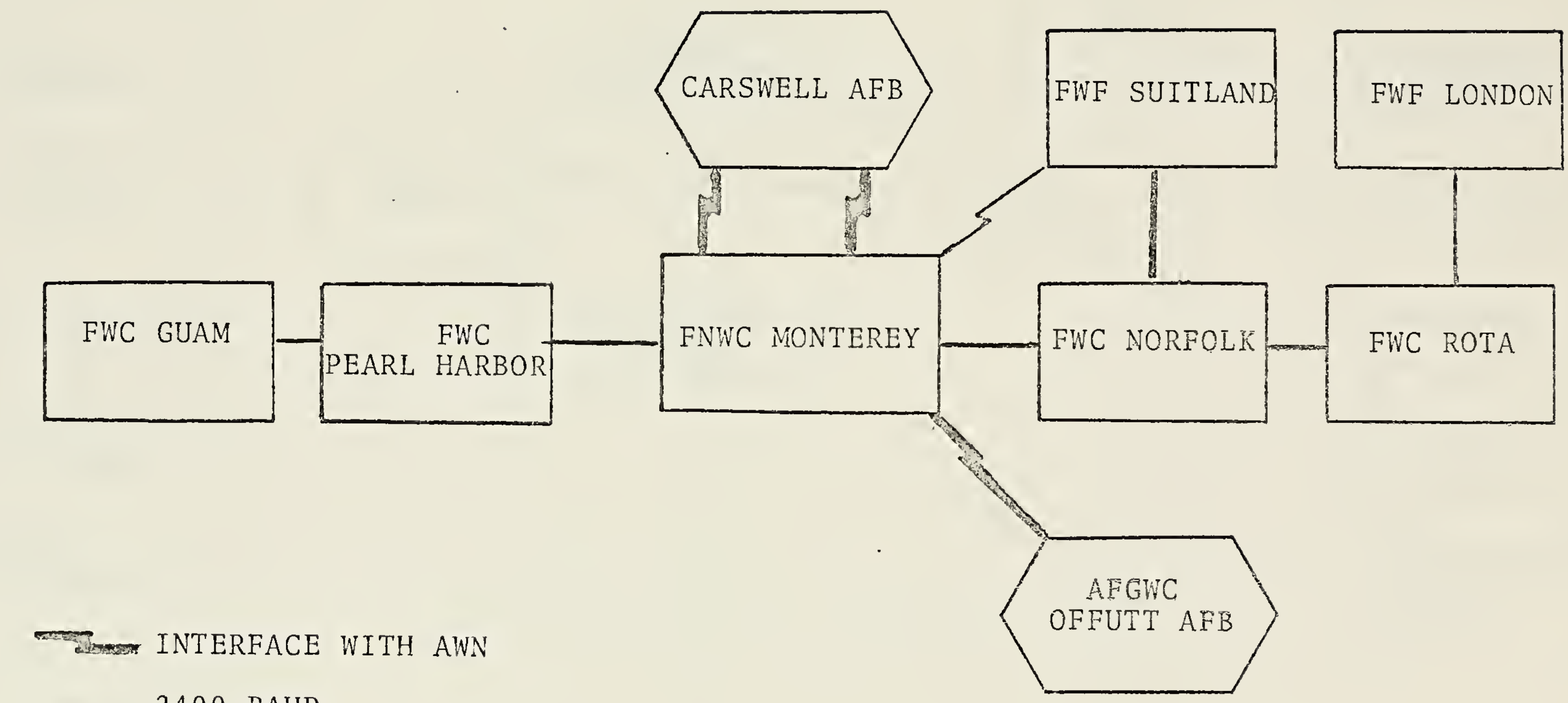


Figure 1

THE TIE LINES

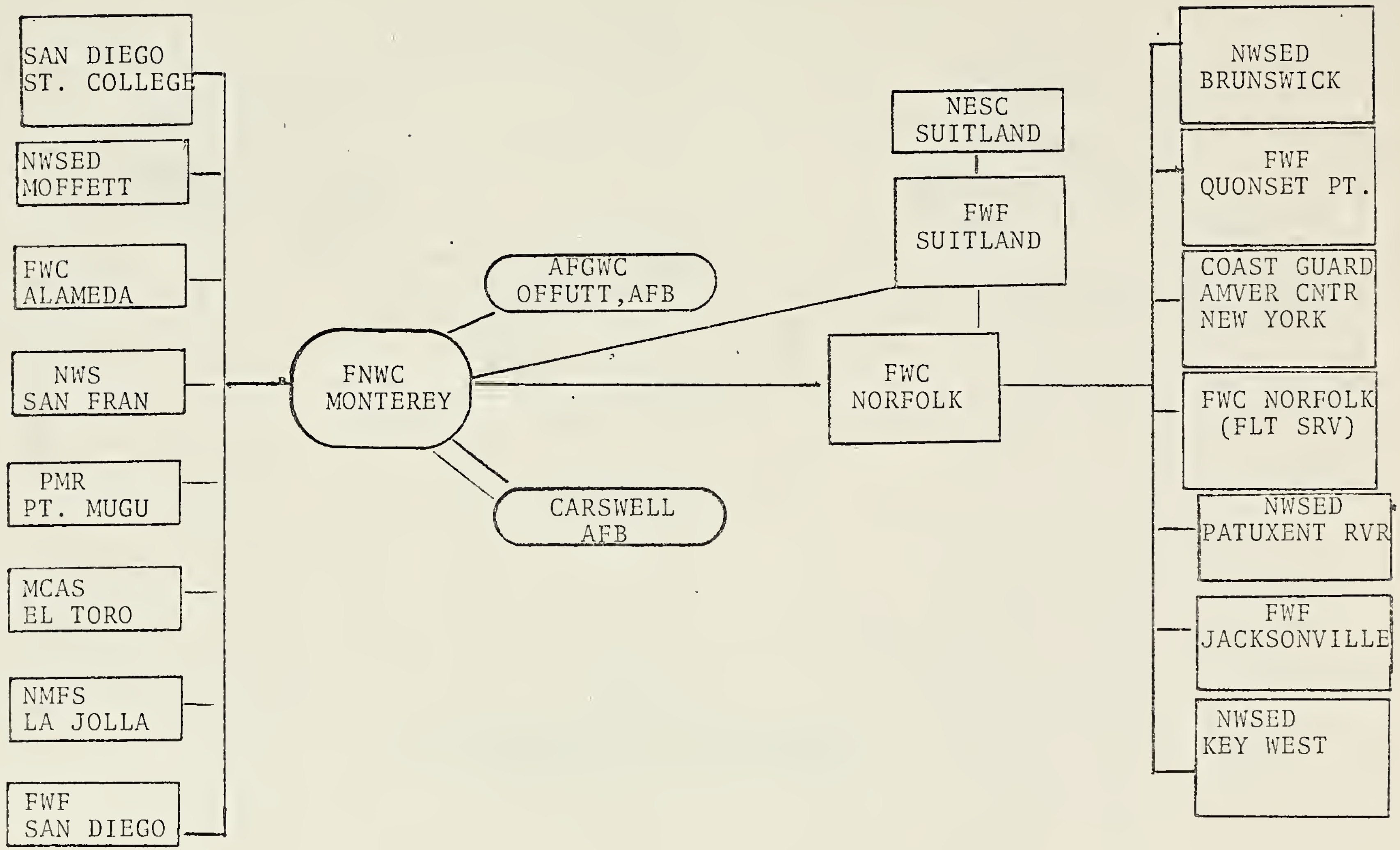


FIGURE 2

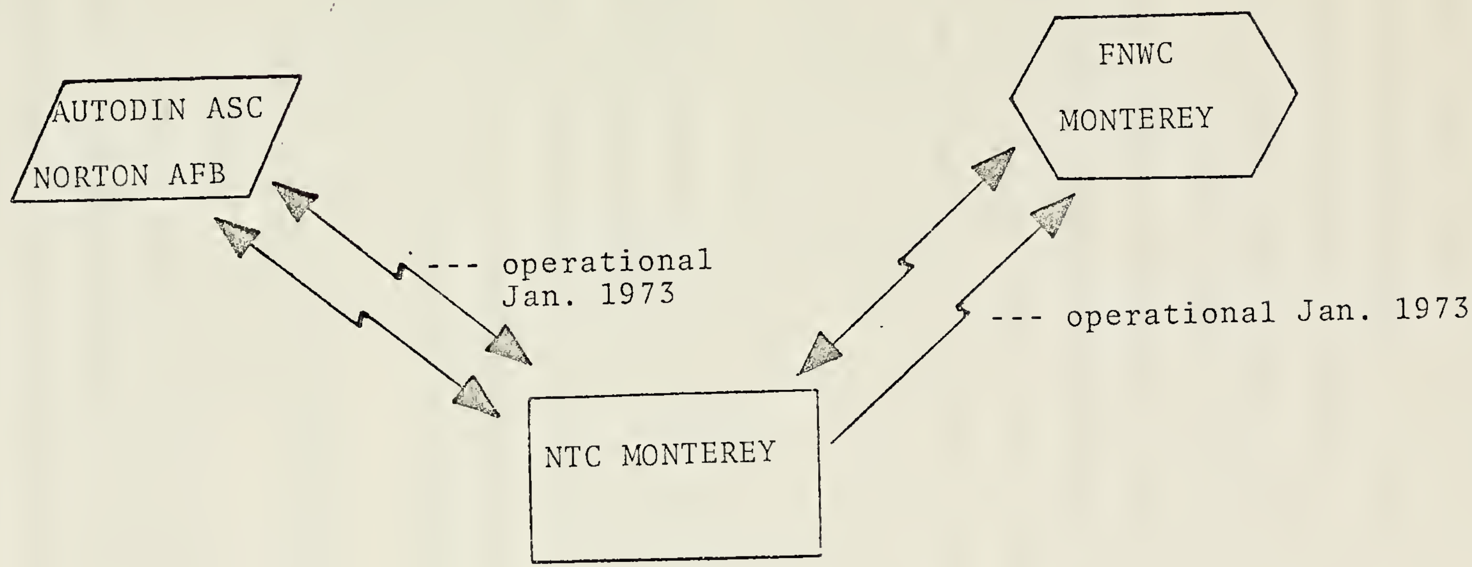


FIGURE 3.

FLEET NUMERICAL WEATHER CENTRAL'S
INTERFACE WITH AUTODIN

a leased voice-grade line with C2 conditioning with either the CDC 160A or CDC 8090 computer at Fleet Numerical Weather Central. Operation of this circuit is full duplex at 4800 BAUD, synchronous transmission. The alternate line is a microwave system leased from the telephone company. It is also a full duplex 4800 BAUD line. The primary traffic on this circuit is raw data. This circuit is not crypto-protected.

The second interface with the Automated Weather Network is a circuit connecting Fleet Numerical Weather Central with the Global Weather Center at Offutt Air Force Base. Communications facilities to and from Offutt are the same as those to Carswell. The only difference is that the alternate line from Offutt to Monterey is via the Automated Weather Network to Carswell, and thence via the primary circuit to Fleet Numerical Weather Central. This circuit is also not crypto-protected.

The circuit from Carswell to Monterey inputs an average of 630 bits per second of raw data into Fleet Numerical Weather Central. This path carries approximately 50 million bits of information during an average operational day. The circuit to the Global Weather Center is presently used for about one hour per day (15 minutes-four times per day). This traffic consists of mutual exchanges of evaluated meteorological data.

2. Naval Environmental Data Network Circuits

a. High-Speed Circuits

The secondary data route for Fleet Numerical Weather Central is via the Naval Environmental Data Network. This network consists of high-speed leased lines connecting the various Fleet Weather Centers and Fleet Numerical Weather Central. There are two mainline circuits in this network which interface with Fleet Numerical Weather Central: one to Fleet Weather Center, Pearl Harbor, Hawaii, and the other to Fleet

Weather Center, Norfolk, Virginia. Transmission to these two Fleet Weather Centers is accomplished by identical equipment. Each Fleet Weather Center has three computers to handle and route data: a CDC 3100, a CDC 8490, and a CDC 160. The primary lines are leased voice-grade lines with C2 conditioning operating full duplex, 2400 BAUD, with serial transmission. Information is forwarded from Fleet Weather Center, Pearl Harbor, to Fleet Weather Center, Guam, and from there to all Western Pacific users. Information is also forwarded from Fleet Weather Center, Norfolk, to Fleet Weather Center, Rota, Spain, and to Fleet Weather Facility, London, for all European users. Norfolk also supplies finished products to a multi-drop network on the East Coast. This network, known as the East Coast Tie Line, is similar to the one on the West Coast which will be discussed later. The Naval Environmental Data Network circuits are not crypto-protected. These two paths input an average of 50 million bits of information during an average twenty-two hour operational day.

There is a new 4800 BAUD, full duplex circuit installed solely for the purpose of transmitting satellite data from Fleet Weather Facility, Suitland, Maryland. This circuit is not fully operational and is not crypto-protected.

b. West Coast Tie Line

The final Naval Environmental Data Network circuit which connects to Fleet Numerical Weather Central is the West Coast Tie Line. This line ties together a large number of users on the West Coast. Most of these users simply collect and use the products supplied to them by Fleet Numerical Weather Central. This line is a leased, voice-grade, half duplex line with C2 conditioning operating at 2400 BAUD, using synchronous transmission. Stations are connected to the line in a

multi-drop arrangement. The input to this line is from two magnetic tape units which are fed from either of the two CDC 3200 computers. At each receiving station, there are two CAL-COMP plotters capable of receiving digital weather maps as well as a teletype. This circuit is also not crypto-protected.

3. Analysis of the Automated Weather Network and Naval Environmental Data Network Circuits

If one had to characterize the communications circuits discussed so far and used for the collection and dissemination of meteorological and oceanographic information, the words "high volume", "high speed", and "automation" immediately come to mind. Environmental observations are collected from worldwide sources at Monterey. These observations, both meteorological and oceanographic, are transmitted to the Fleet Numerical Weather Central where they are quality-checked, sorted, and edited by automatic programs. Then analysis and prognostic programs take over, and basic processed data are transmitted to the Fleet Weather Centers, computer-to-computer, at the equivalent of 4800 teletype words per minute. At the same time, data is being automatically sent and received at the equivalent of 9600 words per minute, computer-to-computer, with the Automated Weather Network. This same process takes place over almost all the various communications links. Most of the analysis and dissemination processes are completely automatic, utilizing modern computer and ancillary equipment coupled with high-speed, highly efficient, three continent, communications links.

These communications networks provide Fleet Numerical Weather Central with the major portion of its data (approximately 120 million data bits per day). This is an enormous amount of data and is most

important to Fleet Numerical Weather Central, but these networks suffer from certain major disadvantages.

4. Disadvantages of These Circuits

a. All of these networks are uncovered. This lack of crypto-protection means that all classified traffic, Encrypted for Transmission Only (EFTO) and higher, transmitted to and from Fleet Numerical Weather Central cannot be sent over any of these paths. The significance of this disadvantage is fully realized when one understands that all record traffic sent to and from all Navy ships has as its minimum classification, unclassified (EFTO). Record traffic is defined as all the communications between one unit and another, conducted by means of a teletype. For Navy ships, this is all communications, exclusive of those conducted by means of a voice radio-telephone circuit.

b. With presently installed equipment, there is no way for digital data to be sent between a ship and a shore station. The Naval Environmental Data Network and the Automated Weather Network are digital networks and connect the ground stations. At sea, there are some ships equipped with the Naval Tactical Data System which can communicate with each other in digital form using a data link (Link 11), but there is no present means for interfacing these two digital networks. This problem is being looked at in relation to the utilization of the future Naval Communications Satellite, but as yet there is no foreseeable solution to this problem.

5. Interface With the Naval Communications System

As a result of these problems, the final communications path to be utilized by Fleet Numerical Weather Central comes into play. This path interfaces Fleet Numerical Weather Central with the Naval Communications

System. Until January 16, 1973, this path consisted of a full duplex, crypto-protected, 100 word per minute teletype link from Fleet Numerical Weather Central to the Naval Telecommunications Center. This link is called the "pony loop". The sending and receiving equipment at Fleet Numerical Weather Central consists of magnetic tape units, punched paper tape units, or teletypes with manual interfaces to the computers.

At the Naval Telecommunications Center, there is another manual interface. It is this manual interface that receives the most attention in this thesis. At this manual interface, messages, in the form of punched paper tape, are transferred from one teletype to another. This is where a great deal of manual record-keeping takes place, and where the man processes the message. At this interface, messages to and from Fleet Numerical Weather Central are transferred between the 100 word per minute teletype "pony loop" circuit and a Western Union (manufacturer) AUTODIN Mode 5 terminal. This terminal is a 100 word per minute teletype connected to a full duplex crypto-protected line terminating at the Defense Communications System Automatic Switching Center, Norton, California.

These two circuits, with the manual interface at the Naval Telecommunications Station, Monterey, connect the Fleet Numerical Weather Central with the Defense Communications System and eventually with any military unit and civilian user, or provider, of weather information. The Defense Communications System is that system of high-speed (2400 or 4800 BAUD), long haul, digital communications lines and switches which interconnect all the land-based communications stations within the Department of Defense throughout the world.

a. A Representative Example

For example, in order for Fleet Numerical Weather Central to

send a message of any type to a Navy ship somewhere off the coast of northern California (i.e. off Monterey) it would transmit that message over the "pony loop" to the Naval Telecommunications Center, Monterey, at 100 words per minute. After certain record-keeping functions were performed, that message would be re-broadcast over a 100 word per minute circuit to the AUTODIN Automatic Switching Center at Norton Air Force Base in southern California. Using automatic message switching, the message would then be switched over to Defense Communications System lines to the AUTODIN Automatic Switching Center at McClellan Air Force Base in northern California at 2400 BAUD. Using automatic switching again, the message would then be sent over Naval Communications Command lines at 2400 BAUD to an AUTODIN Mode I terminal at Naval Communications Station, San Francisco. Using an IBM 360/20 computer as a message processor, this message would then be automatically switched internally to the appropriate punched paper tape unit, where the paper tape would then be torn off and manually entered on the outgoing circuit presently copied by that ship. This would be a 100 word per minute high-frequency radio link. This message would be in encrypted form at all times when it was traveling over any of the communications links, but would be in plain text at any one of the nodes.

Until automated systems are installed, something must be done to upgrade the present system. Although the Naval Telecommunications Center, Monterey, is only a minor node in the entire system, many of the lessons learned can be applied to other communications centers.

b. Machine Capabilities

Returning to the contribution this telecommunications center makes toward the accomplishment of Fleet Numerical Weather Central's

missions, an understanding must be gained of the relationship between BAUD and words per minute. Using rounded figures, 100 words per minute is approximately equal to 75 bits per second. However, if the overhead is discounted, this rate is reduced.

By this, it is meant that the digital traffic sent over AUTODIN or over any of the digital weather networks uses synchronous transmission with control bits every 80 characters, while the teletype uses a synchronous transmission with 3 of every 11 bits used for control. Because of this difference in the mode of transmission, the teletype carries only about two-thirds the amount of information at any rate of speed as a synchronous system. Therefore, 75 bits per second is effectively 50 BAUD when comparing the two different transmission modes.

At 100 words per minute, the maximum one-way throughput of this teletype link is about four million bits per day. This is a very small amount when one considers that on an average day, Fleet Numerical Weather Central inputs approximately 120 million bits by means of its other communications channels. This means that this telecommunications center, working at its maximum capability, can supply a little over three per cent of Fleet Numerical's data.

To say that the loss of this channel would represent only a three per cent loss in communications capability would be unrealistic. This channel fills a unique role in Fleet Numerical Weather Central's overall communications. Over this path are carried all messages to and from Navy ships, as well as the vast majority of Fleet Numerical's operational and administrative message traffic. Any other traffic of this sort is sent via the U. S. Mail or conducted over the telephone.

F. THE NAVAL TELECOMMUNICATIONS CENTER, MONTEREY

How capable is this center? Are its capabilities measured only in terms of the machines on the circuit, or are there other factors involved? The simulation developed for this thesis will answer those questions.

First, the outgoing traffic will be examined. As shown in Appendix A, this path is perfectly capable of handling Fleet Numerical Weather Central's outgoing traffic. From July, 1971, to July, 1972, outgoing traffic of all kinds through Naval Telecommunications Center, Monterey, has varied between 1000 and 3500 messages per month. Fleet Numerical Weather Central's traffic accounts for well over 90 per cent of that volume.

It is the incoming message volume that presents the greatest problems. In the recent past, all incoming traffic volume, with the exception of those messages to Fleet Numerical Weather Central, has remained at a fairly constant 2000 messages per month. Incoming traffic to Fleet Numerical Weather Central has increased significantly since January, 1971. For about two years until July, 1971, incoming messages to Fleet Numerical Weather Central, routed through the Naval Telecommunications Center, oscillated around a relatively constant 4000 per month.

1. Acquisition of the OTSR Function

In August of 1971, Fleet Numerical Weather Central took over the Optimum Track Ship Routing (OTSR) function from the regional Fleet Weather Centers. This OTSR function is a very important service provided to United States warships and merchant ships. The ships file an advance copy of their expected movements across the oceans, as well as any deviations in their movements from the original track.

Fleet Numerical Weather Central then advises the ships in advance which ocean routes to take to get the best weather and calmest seas. Any changes to the original recommendation are also sent to the ships when en route. When the need arises, storm warnings are also sent to these ships, as well as to all United States ships in a storm's path.

Before assigning this function to Fleet Numerical Weather Central, quite an extensive study was conducted by the Commander, Naval Weather Service Command, beginning in April of 1971, concerning the feasibility of this change. All concerned parties were consulted and a great deal of advance preparations were made. Of particular attention in this study was the ability of Naval Telecommunications Center, Monterey, to handle the increased message load. At the time, the Commanding Officer of the Naval Postgraduate School, then in charge of the telecommunications center, seemed to be concerned with some sort of fairness doctrine. He reported that the increased message load would increase Fleet Numerical's share of the traffic volume from some 66 percent to about 80 per cent without any man-power support from Fleet Numerical Weather Central. There seemed t be no real concern over actual message volume prior to the acquisition f the OTSR function.

As a result of this study, there were no changes whatsoever made in the manpower, material, or procedures at the telecommunications center prior to 1 August 1971. When the messages began arriving on that day at twice the rate of the previous day, as a result of the OTSR acquisition, everyone at the telecommunications center was taken by surprise. No one had predicted a doubling of the volume. The internal handling procedures coupled with the message volume caused a change from a four-section watch to a three-section watch (eight hours on, sixteen hours off, seven days per week).

On the sixth of August, a request for more men went out in order to resume the four-section watch. After a very traumatic month, manpower was increased by three, some outside collateral duties of the radiomen were eliminated (such as changing combinations at the student mail center and burning all the Postgraduate School's classified material), and some internal procedures were changed slightly. There was an elimination of non-OPNAV INST 5500.40B required stamps on messages, and an elimination of the radiomen hand-carrying all messages to the action officer for his signature. Instead, customers came to the telecommunications center and picked up their messages; a signature was required for secret messages only.

As a result of these changes, the telecommunications center found that it could just barely handle the traffic load. There were peak periods during the day when very large queues were formed, and slack periods when the queues could be reduced; but, in general, the operation was still marginal.

2. Change in Control

The Naval Telecommunications Center operated for about eight months under an incoming traffic load which oscillated around a mean of 8000 messages per month. During the entire period, it was realized that the operation was marginal. As a result of numerous requests for help, on June 1, 1972, the telecommunications center was taken away from the operational control of the Naval Postgraduate school and consolidated under the command of the Commanding Officer, U. S. Naval Telecommunications Station, San Francisco. This change was made so there would be better-informed personnel representing the interests of the telecommunications center, and so that fluctuations in personnel

could be rapidly taken care of by assigning Temporary Additional Duty (TAD) personnel from San Francisco. Repairs could then be made much more rapidly by sending qualified repairmen down from San Francisco. Prior to this time, the telecommunications center had to borrow semi-qualified repairmen, as the need arose, from the Electrical Engineering Department of the Naval Postgraduate School. This change eased the burden of responsibility at the Naval Telecommunications Center, Monterey.

3. Change in Reporting Procedures

In July, 1972, the situation became worse. As a result of a dialogue among Fleet Numerical Weather Central; Commander, Naval Weather Service Command; and Commander, Naval Communications Command, a relatively minor (or so it seemed) change was made in the reporting procedures for ships reporting their oceanographic and meteorological observations. Fleet Numerical Weather Central was displeased with the time delays found in the system of reporting procedures for ships' bathythermograph reports (oceanographic) and weather reports (meteorological).

Under the old procedure, all U. S. Naval ships at sea were required to send their bathythermographic reports (four per day) and weather reports (two per day) to the nearest Fleet Weather Center. At the Fleet Weather Center, the data would be held long enough for internal usage. Messages would then be sent over the Naval Environmental Data Network to Fleet Numerical Weather Central with the ship's name deleted from the message. The transmission over the Naval Environmental Data Network was unencrypted while the transmission to the Fleet Weather Centers from the ships would be encrypted. There was generally a four-hour delay between the transmission by the ship and the reception by Fleet Numerical Weather Central, caused by hold-ups at the regional

Fleet Weather Centers. The Naval Telecommunications Center, Monterey, was not included, nor its capabilities considered in making the change.

This "minor" change consisted of telling all ships to send their reports directly to Fleet Numerical Weather Central and in addition, to send an information copy to the regional Fleet Weather Centers. For a few months, these messages were sent over the Naval Environmental Data Network to Fleet Numerical Weather Central, as previously described, but this practice has been discontinued.

The increase in traffic volume resulted in what has been described by the center personnel as "utter chaos". In July, approximately 20,000 messages were sent through the telecommunications center to Fleet Numerical Weather Central. This was approximately two and one-half times the traffic volume just barely handled in June. In October, the busiest month to date, over 24,000 messages to Fleet Numerical Weather Central were processed.

To their credit, the assigned personnel at the telecommunications center adopted a "can do" attitude and coped with these problems. The formal message handling procedures which had been adopted when the center's entire message load, both incoming and outgoing, was less tha 6,000 messages per month, were informally ignored. The only criterion was to get the traffic out. As the simulation will show, the formal procedures were so time-consuming that they could not have allowed the passage of the amount of message traffic that passed through this telecommunications center.

4. <u>The I. G. Inspection</u>

a. Informal Recommendations

In September, 1972, the Naval Telecommunications Center,

Monterey, underwent an inspection by the Inspector General of the Navy (I. G.). As a result, the informal message handling procedures were formalized, and thus a great reduction in the time and effort required to process each message was realized. The I. G. team made informal recommendations concerning the administrative records which were kept for each message. It recommended that most of the records be eliminated since:

(1) there was no time to maintain them;

(2) they were not being maintained properly;

(3) they were not required by COMNAVCOMM.

In fact, most of these records were maintained because that was the way it had always been done. These recommendations met with enthusiasm on the part of all hands and were immediately implemented.

b. Formal Recommendations

The I. G. inspectors made some formal recommendations concerning equipment changes. Beginning with the new traffic load in July, 1972, the 100 word per minute teletype links began to become saturated with incoming traffic for Fleet Numerical Weather Central. Starting in July, the Mode 5 link between the Telecommunications Center and its Defense Communications System interface at Norton Air Force Base became the busiest of any at Norton.

At 100 words per minute (50 BAUD effective) there is a maximum amount of traffic that can be sent during any particular period. That maximum was reached numerous times. This maximum was measured on numerous occasions as 8000 line groups per day (an AUTODIN term).

Each line group consists of 80 characters plus two start and two stop characters. Long-term data on message lengths at the

telecommunications center shows that the average message consists of ten line groups. This means that the maximum machine capability over any twenty-four hour period is 800 average sized messages or 33 1/3 messages per hour. If at any time this rate is approached, a queue is formed at the AUTODIN Switch at Norton. Beginning in July, 1972, it was not uncommon for queues of 50 or more messages to be formed several times per day. In fact, in October, 1972, it was not at all uncommon to have over 800 messages per day sent to Fleet Numerical Weather Central alone.

In order to get this volume of traffic through to Fleet Numerical, an alternate route was established. Whenever a queue of 50 or more messages developed at Norton, these messages would be "alt-routed" to McClellan, and then to Fort Ord. The duty officer at Fort Ord would then call the Naval Telecommunications Center, Monterey, to inform them that incoming traffic was being received for them. A radioman would then drive to the communications center at Fort Ord, pick up the hard copies of the messages and the punched paper tapes, and drive to Fleet Numerical Weather Central. The radioman would then show the watch officer the messages and get an indication from him of how time-sensitive the information was. The radioman would drive back to the telecommunications center and send the time-sensitive traffic immediately over the "pony loop". The other traffic would be sent whenever there was capacity available on the "pony loop". This method of communications obviously needed changing.

By the time of the I. G. inspection, the Naval Telecommunications Center had been requesting, to no avail, an upgrading of its capabilities. The formal report of the I. G. added credence to their

requests by recommending an immediate upgrading of the system. In October, 1972, Commanding Officer, Naval Communications Station, San Francisco, (the Naval Telecommunications Center's next senior in the chain of command) made a formal request to Commander, Naval Communications Command for the following:

(1) Immediate allocation for and installation of an additional 100 word per minute Mode 5 terminal.

(2) Immediate allocation for and installation of another "pony loop" to Fleet Numerical Weather Central. This was to be a simplex circuit for one-way only transmission.

(3) Installation of a 2400 BAUD, Mode I AUTODIN terminal, to include a magnetic tape unit at Fleet Numerical Weather Central immediately adjacent to the computer facility. This was seen as the optimum solution to the problem even though it was realized that there is currently no space available to put one in.

These recommendations were adopted with the following results:

(1) When the new Fleet Numerical Weather Central computer facility is constructed (sometime in FY 1976), it is currently planned to have a Mode I installed immediately adjacent to the computers.

(2) The new simplex "pony loop" was installed in late December, 1972.

(3) The new Mode 5 was installed in early January, 1973, and both new links became operational on 16 January 1973.

III. APPROACH

The approach utilized to conduct this analysis was to develop a computer simulation model of the Naval Telecommunications Center, Monterey. Numerous interviews with the personnel stationed there, as well as many visits to the center, provided data concerning how the telecommunications center functioned. This data, coupled with the monthly traffic summaries (enclosed in Appendix A) was used to simulate the message handling function of the facility.

The mechanical capacities of the various machines and transmissions systems in and out of the telecommunications center were known. Equipment utlization could be found by dividing actual message processing rate by equipment processing rate. Personnel limitations were unknown. If one asked a radioman how busy he was during this time, the answer would be, "very busy". It is the purpose of this thesis to quantify what "very busy" meant.

A casual observation of the operations at the telecommunications center indicates that message processing takes too much time. The term message processing, in general, means everything done to a message. It was the author's opinion at the commencement of this effort that it was the time involved in processing each message through the facility, rather than the machine capability, that limited the through-put of the system.

A. WHY SIMULATION?

Simulation is a technique that provides an effective means to test, evaluate, and manipulate a system or facility without any actual direct interference with it. Days or months of system operation can be simulated in a matter of minutes or hours using a computer. It must be remembered that simulation is but a symbolic representation, often an

abstract representation--not a precise analog. It can, however, provide comparisons between systems which would not be possible to achieve in any other way.

There are several simulation languages available today, of which IBM's General Purpose System Simulator (GPSS) is one example. As the name implies, this is a general purpose simulation language that permits a system to be described and modelled. This is a highly flexible language that can be applied to the simulation of many systems. The GPSS is also characterized by its provisions for making adjustments to basic program logic.

B. FUNCTIONS OF THE TELECOMMUNICATIONS CENTER

The Telecommunications Center provides four distinct services as follows:

(1) The reception, processing, and re-transmission of messages to Fleet Numerical Weather Central. (FNWC INCOMING)

(2) The reception, processing, and re-transmission of messages from Fleet Numerical Weather Central. (FNWC OUTGOING)

(3) The reception, processing, write-up, and filing of messages to the Naval Postgraduate School. (NPGS INCOMING)

(4) The reception, processing, write-up, and transmission of outgoing messages from the Naval Postgraduate School. (NPGS OUTGOING)

C. MESSAGE PROCESSING TIMES

Messages in each category are assumed to be equally likely to be processed at any time during the day. Furthermore, messages from all categories wait in a single queue for processing.

The watch section of three men (a supervisor and two operators)

works as a team to process the traffic. The two operators are engaged in actual message processing, while the supervisor is responsible for the overall operation of the telecommunications station. The combined effect of the two operators working together on separate functions for each message is one service time for each type of message, represented by one service facility. The message processing times for each type of message were approximated in whole minutes, and a uniform distribution of message processing times was assumed. These processing times represent realistic operator performance times over a twenty-four hour day. Low processing times represent an operator working at a pace likely to result in mistakes, or an operator actually skipping some logging functions due to a high traffic load. The high times indicate slow work.

The message processing times are broken down into two time frames. These time frames cover the period prior to September, 1972, and the time frame after message processing was streamlined due to the recommendations of the I. G. Inspectors in September.

1. Prior to the I. G. Inspection

The processing times prior to September, 1972, were as follows

a. FNWC INCOMING--three minutes ± two minutes, uniformly distributed. (Refer to Figure 4)

This time includes the first operator at Station B checking the message header for completeness and accuracy. Then he would log the message number, date-time group, time of receipt, message precedence, classification, to whom the message was to be sent, and signed for the message. The punched paper tape was torn off and handed to the second operator at Station E who logged the message number, originator, date-time group, classification, precedence, time of delivery, and

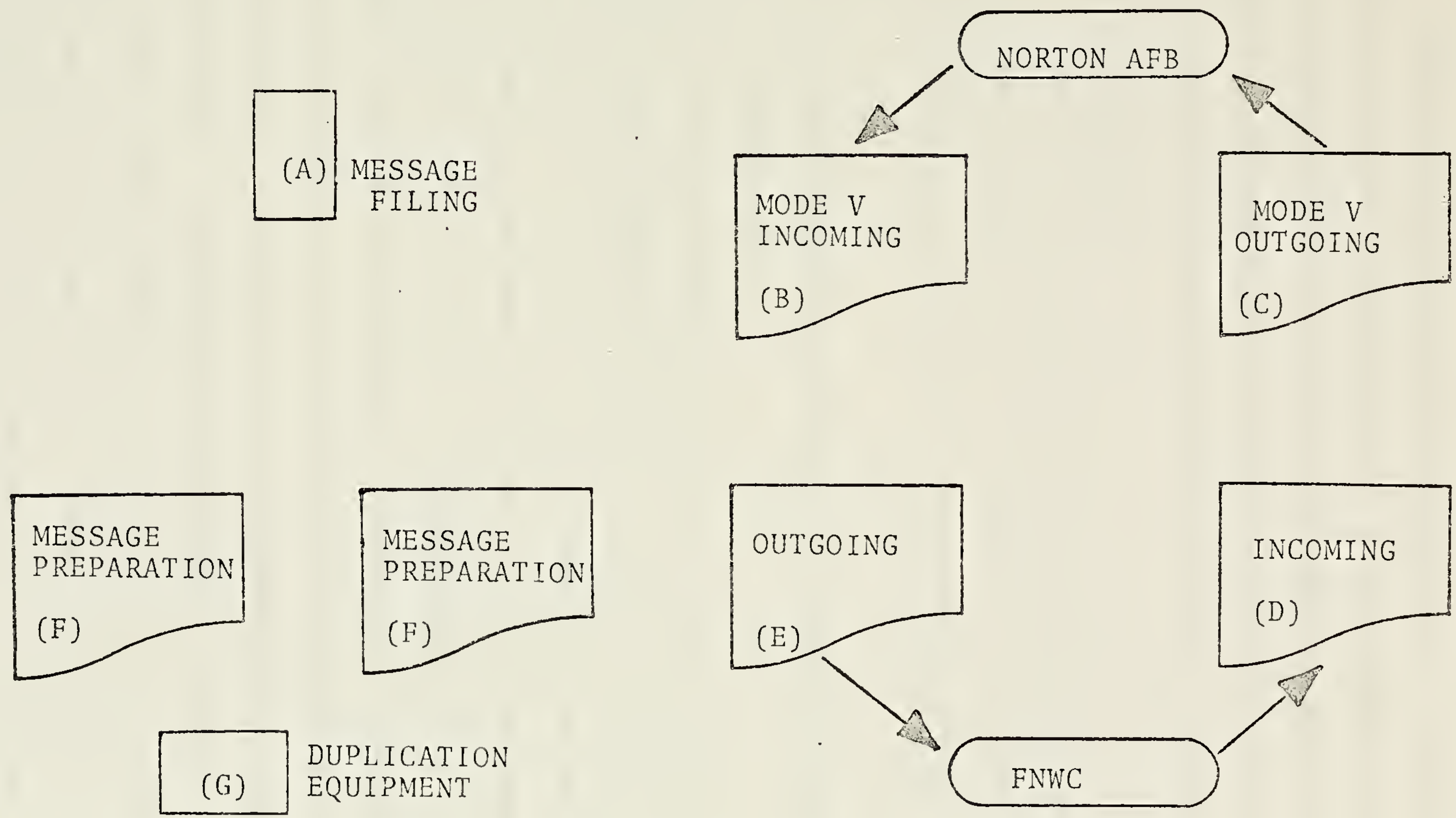


FIGURE 4.
NAVAL TELECOMMUNICATIONS CENTER, MONTEREY
CONFIGURATION PRIOR TO 16 JANUARY 1973

and signed the outgoing log. He then mounted the paper tape on the "pony loop" tape reader and transmitted the message to Fleet Numerical Weather Central. If the message was classified secret, then the same information as before, plus the number of in-house copies of the message made, and the copy and tape destruction records were recorded at Station A. There is an average of ten to fifteen secret messages per day.

b. FNWC OUTGOING--three minutes $\pm$ two minutes, uniformly distributed.

This procedure involved exactly the same procedure as the previous operation, except the first operation was performed at position D; then that operator handed the tape to the second operator at Position C.

c. NPGS INCOMING--three minutes $\pm$ two minutes, uniformly distributed.

This time included the time for the same procedures as outlined for FNWC INCOMING for the first operator, who then handed the printed copy of the message to the second operator. The second operator, in turn, recorded on the message the time of receipt and message number, as well as the internal routing. The required number of copies were made using the duplication equipment at Station G. The messages were stamped with the appropriate classification; one or more copies were stamped with ACTION OFFICER and another stamped ORIGINAL. The message copies were filed in the appropriate pigeonholes at Station A. The rarely received secret messages were logged in the Secret Log at Station A. There was also a log maintained to obtain the signature of the message action officer or his representative, if appropriate, which required recording for each message. This usually occupied the supervisor's time.

d. NPGS OUTGOING--eight minutes ± two minutes, uniformly distributed.

This time included receipt of the handwritten message. The message was typewritten at Station F, and the appropriate routing indicators were assigned to the message. Typing a message on a teletype produces a punched paper tape at the same time. This paper tape was run through the tape reader at the preparation teletype, and another printed copy was made to make a comparison with the original to check for correctness. If incorrect, the tape was spot corrected. If correct, the tape was given to the second operator at Station C. He filled in the appropriate logs as in Step 2 of the FNWC OUTGOING processing function. At the same time, the first operator would go to Station G and prepare duplicate copies for internal processing. He would then perform the stamping, filing, and logging functions as described for NPGS INCOMING for internal routing.

2. <u>After the I. G. Inspection</u>

These time-consuming procedures were drastically reduced as a result of the increased message load and the I. G. inspection. The basic change was the elimination of the logs described under FNWC INCOMING messages. Even the Secret Log has been eliminated for FNWC INCOMING and OUTGOING. The rationale for this is that the telecommunications center provides nothing more than a message switching function, and is not a holder of classified data.

The incoming and outgoing logs which were maintained beginning in September, 1972, were sheets of paper consisting of long lists of numbers. Since each message has a number assigned to it, all that is performed in the logging function is checking the number if the message

is classified Confidential or higher, or circling the number if the message is classified UNCLAS EFTO. The number of UNCLASS EFTO messages per month must be reported to the Commander, Naval Communications Command. The action officer log was also eliminated. In fact, the amount of information logged has been reduced so much that the information contained in the monthly message summaries (Appendix A) is no longer obtainable, with the exception of monthly totals for incoming and outgoing messages.

The new processing times are as follows: (Refer to Figure 4)

a. FNWC INCOMING--mean of one minute, with negligible variance.

This time included checking the message routing indicators and headings for accuracy. The message number was then circled or checked (as appropriate) in the INCOMING log. These functions were performed at Station B. The message tape was then handed to the second operator who performed the same logging functions (check or circle); he then mounted the tape on the tape reader at Station E, and saw that the message was sent out properly.

b. FNWC OUTGOING--mean of one minute, with negligible variance.

This time reduction is for the same reasons as mentioned before. The process is just reversed. The first operator is now at Station D, and the second operator is at Station C.

c. NPGS INCOMING--the same processing time of three minutes ± two minutes, uniformly distributed.

Even though the time involved in the logging function has been reduced, as outlined by the previously mentioned procedures, the majority of time is taken up by the duplication and filing functions. The second change in the processing function for these messages was the

elimination of the action officer log.

d. NPGS OUTGOING--the same amount of time of eight minutes $\pm$ two minutes, uniformly distributed.

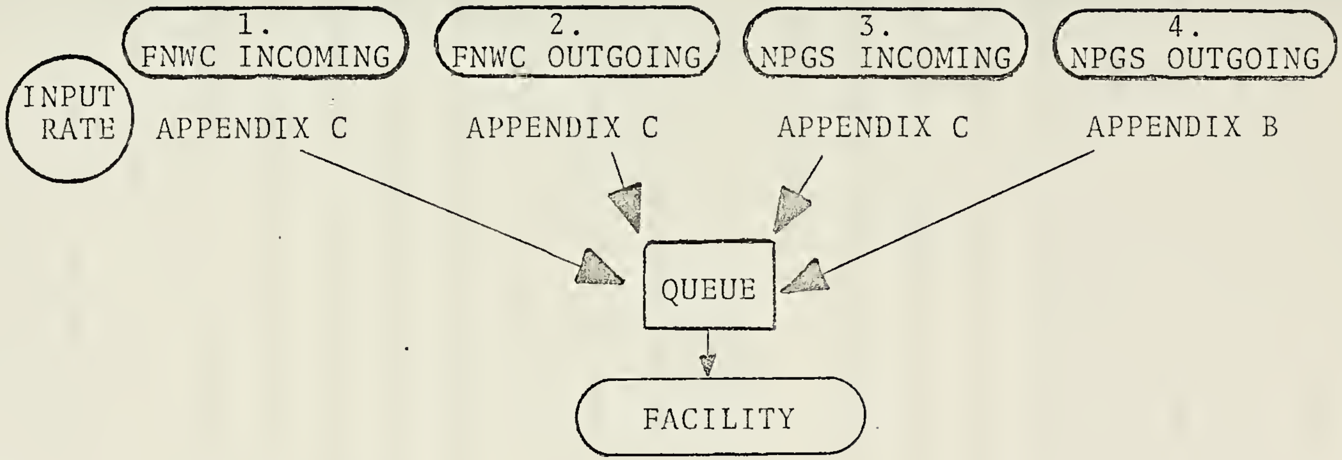
The time to process these messages was the same as before because, except for the changes in one log, the procedures have remained the same.

D. THE SIMULATION MODEL

Once the handling times were estimated, the simulation model was developed. There were four types of messages arriving at the telecommunications center. Each type was arriving at a different rate over a certain period of time. As shown in Appendix A, the daily arrival rates of all types of messages except FNWC INCOMING remained relatively constant. These periods were: prior to August of 1971, from August, 1971, to June, 1972, and from July, 1972, to the present. The simulation covers the two most recent periods.

Once the arrival rates were simulated, the messages would then be simulated to be collected in a single queue (refer to Figure 5). This simulation technique means that, in reality, messages from all four categories had to wait in the form of punched paper tape lying on the floor and printed messages on rolls of paper on the teletypes, for the two operators to get around to processing them. These two operators, working together, provide the same function as a single facility in the simulation. The facility takes messages one at a time, processes it, and then handles the next message.

Now the question of message priorities arises. How are messages of the various precedences (priorities) handled here? ROUTINE, PRIORITY, OPERATIONAL IMMEDIATE, and FLASH are the precedences. In reality,



FACILITY PROCESSING TIMES

PRIOR TO SEPT.72	AFTER SEPT.72
1. 3 min $\pm$ 2 min unif. dist.	1. 1 minute negligable var.
2. 3 min $\pm$ 2 min unif. dist.	2. 1 minute negligable var.
3. 3 min $\pm$ 2 min unif. dist.	3. 3 min $\pm$ 2 min unif. dist.
4. 8 min $\pm$ 2 min unif. dist.	4. 8 min $\pm$ 2 min unif. dist.

FIGURE 5. SIMULATION DIAGRAM

priority is not given to a message because of its assigned precedence. All messages are afforded the same treatment. The first message in is the first message out (first in--first out). Precedence becomes a factor at the two facilities with which the telecommunications center communicates. At both Fleet Numerical Weather Central and Norton Air Force Base, messages of a certain precedence are given priority in the queue over all other messages of a lower precedence, and behind all others of the same precedence. For example, an OPERATIONAL IMMEDIATE message being sent to Fleet Numerical Weather Central via the Norton Automatic Switching Center would enter the queue for transmission to Fleet Numerical Weather Central ahead of all PRIORITY and ROUTINE messages and behind all FLASH and OPERATIONAL IMMEDIATE traffic already in the queue.

E. ARRIVAL RATES

With the basic simulation developed, the four different arrival rates were determined utilizing the data enclosed in Appendix A. This data was broken into two periods--April-June, 1972, and July-October, 1972, reflecting the two most recent, fairly constant, message volume periods. Using this data, probability mass functions over the April-June and July-October periods were plotted for FNWC INCOMING and over the entire seven-month period for the other three (as shown in Appendix B). Then, using the probability mass functions, cumulative distribution functions were derived for use in the simulation (Appendix C) for simulating message arrival rates.

Appendix D, the basic GPSS program for the period prior to July, 1972, has three functions at the top: FNWIN, NPGIN, and FNOUT. The functions represent sample points taken from the cumulative distribution functions (Appendix C) to represent input rate. For example, refer to the basic

program (Appendix D). In the first function (FNWIN), the fourth group is /.67,4.80/. This group refers back to Appendix C. This group means that the probability of the FNWC INCOMING messages arriving at, or less than, the rate of 300 per day (1 message every 4.8 minutes) is .67, as shown on the graph.

The message input rate for NPGS OUTGOING is represented in the basic program (Appendix D) by a GENERATE function (GENERATE 160,160). This form of representation was utilized because of the almost uniform distribution of input rates, as seen on page 5, Appendix B.

IV. RESULTS

Appendices E through L show a representative sample of the simulation results. Before examining these appendices, an analysis must be made of the results as a whole. As previously stated, a simulation is not an exact analog, but rather a representation of the system.

A. OVERALL ANALYSIS OF RESULTS

In Appendix G, the number of entries that passed through the facility was 13,139. When this figure is compared to 11,634 messages handled in the month of June, 1972, which this model simulated, the results show that the message volume in the simulation is some 12 per cent higher than the telecommunications center actually experienced.

In Appendix L, the simulation shows 28,815 messages having entered the system, which, when compared to the 27,540 messages handled by the telecommunications center, is about four per cent high.

In retrospect, some of the disparity can be accounted for. Some of the messages are incorrect when received and thus must be re-broadcast. This process takes time and the replacement message is given the same number as in the incorrect message received. As a result, there are no data available on the amount or even the percentage of messages that must be handled twice.

The simulation output contains many statistics. Those which are of interest are:

1. The Facility Average Utilization, or the extent to which the message processing facilities were busy.

2. The Facility Number Entries, which represents the number of messages handled by the telecommunications center over the period.

3. The Facility Average Time/Tran, or the average number of minutes that it took to process a message, regardless of the source of the message.

4. The Queue Maximum Contents and Average Contents are the maximum and average amounts of messages waiting to be processed by the operators.

By far, the most important statistic computed in this simulation was the Facility Average Utilization. When transactions arrive randomly at a facility, and the facility takes a certain time to process these transactions, inevitably queues or waiting lines will build up. The Facility Average Utilization, in the case of this simulation, is defined as the amount of time the operators spend processing messages, divided by the total amount of time available.

The greater the utilization of the facility, the longer the queues will become. If the facility utilization is .25 then the queue lengths will be very small. If the facility utilization is .90 then the queues will be large. When a single facility for which items are queuing becomes more than 80 per cent utilized, then the queue size increases at an extremely fast rate. Thus a small increase in traffic may cause severe degradation in the performance of the system.

B. COMPUTER OUTPUT STATISTICS

1. The Basic Program

Appendix E shows the results of the basic program run for one month under the average loads that existed prior to July, 1972. The results show that during this period the average utilization of the facility was 95 per cent, well above the danger point previously mentioned. The number of messages processed, from all four categories, was 13,171 and the average time it took to process a message was a little over three minutes. The average queue length was about three messages

and, at one time during the simulated month, the amount of messages waiting to be processed reached a maximum of 23.

2. Sensitivity Analysis

Appendices F through J show a representative sample of the sensitivity analysis run on the basic program. Various parameters were changed to see what effects these changes had on the results.

Appendix F represents a three-month period (April-June). As a result of running the simulation for this length of time, the Facility Average Utilization dropped slightly to .942 and a total of 39,418 messages were processed. The previously mentioned figures from Appendix E dropped slightly in proportion to the slight reduction in average utilization.

Appendix G shows the results of reducing the processing time by one minute for FNWC INCOMING messages (the greatest single source of message volume). This one minute reduction in processing time produced dramatic results in the simulation. Facility Utilization was reduced from .95 to .718, and average time per transaction was reduced from 3.118 minutes to 2.632 minutes. The average queue length was reduced to less than one message with a maximum contents of 7. The average time a message spent waiting in the queue before it was processed was about two minutes.

In Appendix H, FNWC INCOMING average processing time was increased by one minute. The major effect of this change was to create a large queue. Only 598 messages passed through the facility; yet, the queue had already grown to 107 messages and this figure was increasing. The Facility Average Utilization was up to .996 and the simulation terminated, indicating the beginning of a long queue.

Appendix I shows the minor changes in the results of the simulation as a result of reducing the NPGS INCOMING mean message processing time by one minute. These are the same results obtained by reducing the mean processing time by one minute for FNWC OUTGOING. Both these categories of messages have similar volumes. The major result of this time reduction was a slight reduction in Facility Average Utilization from .95 to .908.

Then, the basic program was run for one month with all the mean processing times reduced by one minute. Appendix J shows the results of this major change. The Facility Average Utilization was reduced from the excessive figure of .95 to a more reasonable .639. The average time per transaction was reduced to two minutes, and the average queue length decreased to less than one, with a maximum length of six messages.

3. Message Volume Increase

After conducting this sensitivity analysis, an understanding was gained of the results of varying the different parameters. The simulation was then changed in order to simulate the operation of the telecommunications center after the tremendous increase in traffic volume, as a result of the changes in reporting procedures on July 1, 1972, for bathythermographic and weather reports. This simulation covers the period when the old processing times were in effect prior to the I. G. Inspection. Appendix K shows that a large queue is formed. Of the 199 messages that entered the simulation, 106 remained in the queue and only 93 were processed. In other words, the telecommunications center was able to handle less than half of their message volume using their time-consuming traditional procedures, during the months of July and August, 1972. In reality, the traffic got through although a lot of mistakes were made. Messages

were not handled properly and all of the internal logging was not performed.

4. Decrease in Message Processing Times

Appendix L shows the results of the decrease in handling times brought about by the reduction of a lot of internal paperwork induced by informal recommendations during the I. G. Inspection in September, 1972. Here, the Facility Average Utilization has dropped to a more reasonable .781 and the average time per transaction is only 1.17 minutes. The average queue contents were less than one and the average time a message spent in the queue was 1.44 minutes.

V. DISCUSSION OF RESULTS

This thesis shows that the improvement of manual message handling techniques by the adoption of better and faster methods and procedures will significantly increase overall system performance and efficiency. As message processing techniques are improved, the ability to handle faster data rates will also improve.

The telecommunications center was tasked, more than once, well beyond its normal capabilities. Adequate planning has clearly not been evident in the recent history of the telecommunications center. Planning is the first function of a manager. However, proper planning must involve some prediction of the future as well as a detailed knowledge of the present and past.

A simulation, such as this one, can be used to give the manager of a telecommunications center a detailed knowledge of the present and past by allowing him to measure his center's capabilities. The technique of simulation can then be utilized to test the effects of anticipated future changes in requirements, prior to the time these changes occur. Based on the results of the simulation, management could plan accordingly.

A. USAGE OF THE TECHNIQUE OF SIMULATION

For example, if the telecommunications center had been made aware of the plans to increase its traffic load in July, 1972, a simulation such as this could have been used to forestall that increase, by showing higher authority that it was presently at its limit in volume which could be handled using its present procedures. Then, if given a relatively accurate estimate of the increased load expected, the center could have used a simulation such as this to determine what changes in the time

spent handling each message would have to be made in order to handle the new load. Once this was known, the new procedures could have been developed and adopted. This type of application of the technique of simulation, as well as many others, can be used in the field of telecommunications, where queuing and capacity problems arise with increasing regularity.

B. EQUIPMENT CHANGES

This thesis also shows that the speed and effectiveness of Naval Communications is a function not only of the time spent in the message handling process, but also of the installed equipment's capabilities. Due to increases in the FNWC INCOMING message load, the telecommunications center had its limit reached, first due to its message handling times, and most recently, due to the volume limitations of its installed equipment. Both of these cases indicate inadequate support for Fleet Numerical Weather Central's crucial communications needs.

Despite the fact that the telecommunications center handles a very small percentage of all data used by Fleet Numerical Weather Central, all of the data sent through the telecommunications center is crucial. It is crucial because first, it involves all the command and control traffic sent to and from Fleet Numerical Weather Central. Secondly, to support the Navy's ships, Fleet Numerical Weather Central must send and receive its data by means of the Defense Communications System. The only means of getting oceanographic and meteorological data in support of ships at sea, is to get data in the area where those same ships are operating.

To illustrate how important Fleet Numerical Weather Central considers this data, one must realize that each bathythermograph message is hand-

checked for obvious inaccuracies at Fleet Numerical Weather Central, prior to inputing the data into the computer for use in forecasting. These mistakes can be the result of errors made by the originator, or can be the result of the inherent errors in the Navy's Communications System (high-frequency as the transmission medium, punched paper tape, man-machine interface, etc.). Whatever the reason, Fleet Numerical Weather Central has experienced a one-third increase in the amount of errors in the bathythermographic messages received since it started having them transmitted via the Defense Communications System, as compared with the amount of errors it found when these same messages were transmitted via the Naval Environmontal Data Network.

The telecommunications center was belatedly successful in correcting its handling time problems. Due to the I. G. Inspection it corrected them; however, two months is rather long for the situation to have lasted before positive steps were undertaken to reduce the message processing times.

As far as correcting the machine limitation problem, as of 16 January 1973, the machine capabilities of the telecommunications center were essentially doubled (refer to Figure 6). A full duplex link with Norton Air Force Base was installed, as well as a new simplex "pony loop" for message transmission from the telecommunications center to Fleet Numerical Weather Central.

For example, FNWC INCOMING comes in at Stations B and E and is logged twice (once for incoming, once for outgoing) and then is sent out to Fleet Numerical Weather Central at the adjoining stations (A or F as appropriate). FNWC OUTGOING is still sent into the telecommunications center at Station G, processed, and then usually sent out at Station C.

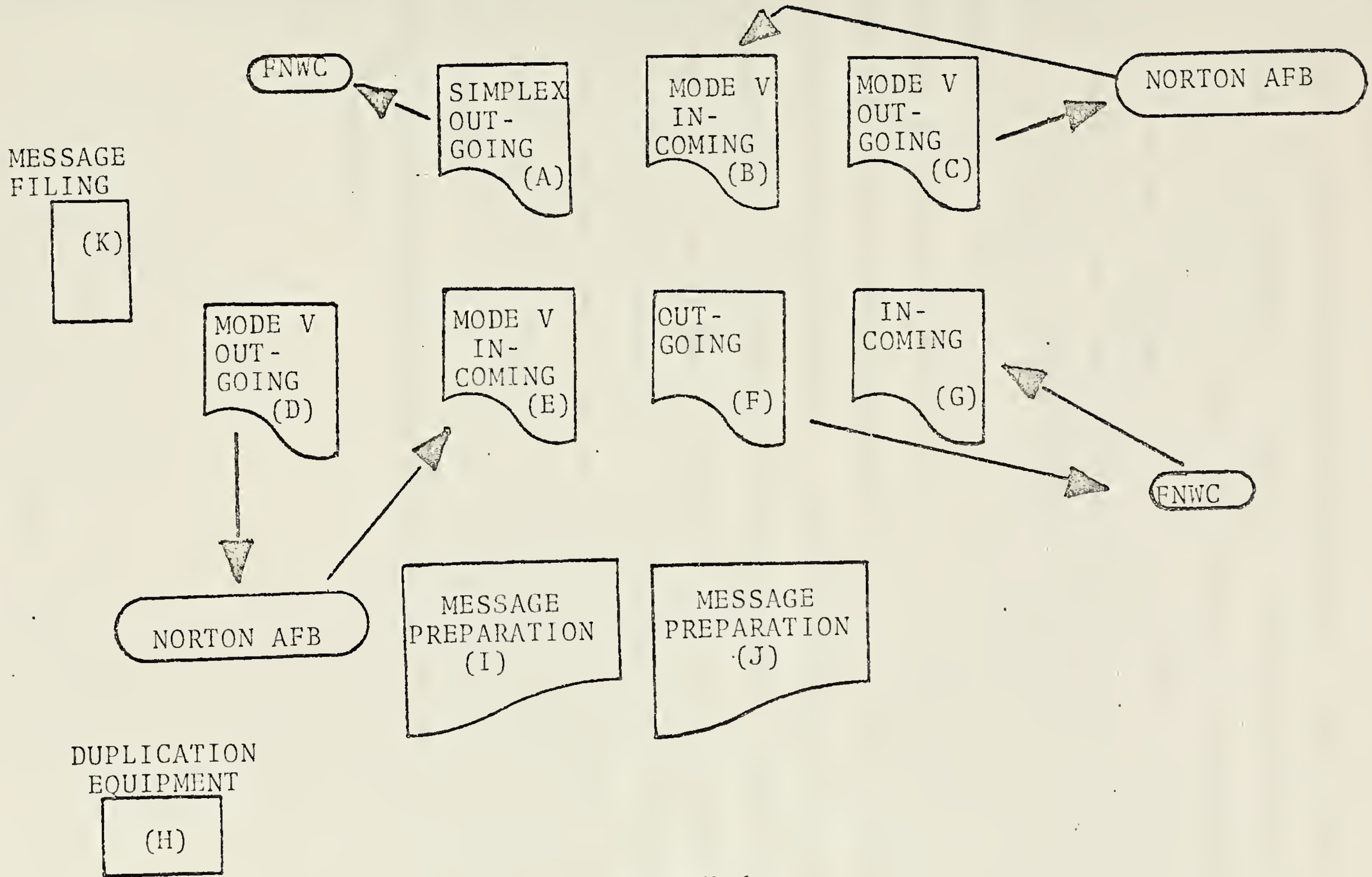


FIGURE 6.

NAVAL TELECOMMUNICATIONS CENTER, MONTEREY
CONFIGURATION AS OF 16 JANUARY 1973

Station D is also an outgoing circuit but is usually used for NPGS OUTGOING. NPGS INCOMING is received on either of the two incoming circuits (B or E).

Despite the fact that the machine capabilities of this center have been doubled, the simulation, as outlined for the period after the I. G. Inspection, still holds true. There are still only two operators directly involved in message processing, and the time to process each type of message remains the same. The telecommunications center is again I/O bound by its procedures, not its equipement. Now that the Automatic Switching Center at Norton can pass its FNWC INCOMING traffic to the telecommunications center twice as fast, it is no longer bothered by the excessive queue lengths experienced in the past, which caused the alt-routing of messages to Fort Ord. Norton's problems have diminished.

It might seem that the telecommunications center's problems have diminished also, since it now has two circuits over which to pass traffic to Fleet Numerical Weather Central. At the current traffic levels this is the case. However, should the traffic load be drastically increasec again, as it has been in the past, the message processing Facility Utilization level will rise above the .78 region where it is presently operating into the so-called danger region above .80, where queues grow at an alarming rate.

VI. RECOMMENDATIONS

A. MESSAGE HANDLING

A variant of Parkinson's law as it relates to Naval Communications states that, "message volume increases over a circuit over time to fill the available capacity." In other words, if the machines can handle 1600 average-sized incoming messages per day, some day in the not too distant future, they will be handling that volume.

Can the message processing function of this telecommunications center, as it is presently configured, handle such a load? Probably not. The message handling procedures in effect today are streamlined as far as possible. The only recourse is to add more men to process the traffic. Since the telecommunications center is not included in the Naval Communications Automation Program, it cannot be funded for automated equipment. As it is presently configured, there is room for four operators per watch section to be involved in the message handling process, without getting in each other's way. The use of four men would, in effect, halve the service times (processing times) for each category of messages, since they would be processing messages in parallel. If the operator manning level were doubled, then the telecommunications center could handle the maximum machine through-put. There are some other recommendations to be made as a result of this study, all of which fall in the general category of machine capabilities.

B. MACHINE CAPABILITIES

1. Fleet Numerical Weather Central

The first recommendation has already been made by the Commanding Officer of the Naval Communications Station, San Francisco, involving

upgrading Fleet Numerical Weather Central's communications capabilities. There is no question about the fact that an AUTODIN Mode I terminal is needed to handle the traffic that presently passes through the telecommunications center. This capability should be placed adjacent to Fleet Numerical Weather Central's computers.

Prior to a single-purpose installation of such sophisticated equipment, a study should be made of the communications requirements and capabilities of all military installations in the Monterey Bay area. Fort Ord, for example, has just recently replaced its 600 BAUD Mode I AUTODIN terminal with new equipment because of a need for the equipment to have a magnetic tape capability. The old Mode I at Fort Ord was operating at 3.5 per cent of its maximum capability. The new equipment is an IBM 360/20 processor controlled 1200 BAUD Mode I AUTODIN terminal which, by deduction, should be operating at an extremely small percentage of its maximum capacity. Are two such high-speed communications devices justified for the Monterey Bay area? This question must be examined with the thought of consolidation in mind, prior to the installation of the new Mode I at Fleet Numerical Weather Central's planned new computer center.

2. Communications with Fort Ord

The next recommendation concerns the contingency alt-route plan in use by the telecommunications center. The present system of having a truck link between the two telecommunications facilities is completely unsatisfactory. A cost and potential utilization study should be initiated concerning the replacement of this system with a full duplex 100 word per minute teletype link. Should the communications links between the Naval Telecommunications Center and Norton by broken for a long

period of time, the expense of installing the circuit and compatible crypto equipment at the two telecommunications centers could be justified by Fleet Numerical Weather Central as an operational necessity, because it would allow a virtually uninterrupted flow of its vital traffic.

3. Crypto-Protection

Since the Naval Environmental Data Network is not crypto-protected, no classified traffic may be transmitted on it. As a result, the Naval Communications System must handle large amounts of data which, if the Naval Environmental Data Network were covered, would be sent via that network. This thesis recommends the initiation of a study to determine the feasibility of providing the Naval Environmental Data Network with the proper equipment so that it can carry classified traffic. This would reduce the requirements placed on the Defense and Naval Communications Systems.

MESSAGE VOLUME

INCOMING - APRIL 1972

DAY	FNWX	NPGS	TOTAL
1	269	44	313
2	260	23	283
3	280	29	309
4	304	59	363
5	306	46	352
6	300	57	357
7	302	63	365
8	273	42	315
9	271	17	288
10	306	33	339
11	322	62	384
12	325	59	384
13	282	71	353
14	277	57	334
15	265	42	307
16	238	28	266
17	286	35	321
18	294	61	383
19	309	58	317
20	266	55	271
21	329	54	340
22	263	54	383
23	255	16	360
24	305	35	340
25	325	58	383
26	305	55	360
27	338	66	404
28	317	56	373
29	297	51	348
30	263	27	290
	8732	472	9204

APPENDIX A

MESSAGE VOLUME

OUTGOING - APRIL 1972

DAY	FNWC	NPGS	TOTAL
1	84	6	90
2	81	0	81
3	83	7	90
4	73	4	77
5	54	14	68
6	49	13	62
7	48	11	59
8	69	5	74
9	81	1	82
10	73	5	78
11	68	18	86
12	49	8	57
13	40	16	56
14	66	11	77
15	49	7	56
16	58	6	64
17	68	4	72
18	64	12	76
19	58	16	74
20	46	11	57
21	55	9	64
22	67	9	76
23	61	2	63
24	63	6	69
25	68	15	83
26	54	9	63
27	51	4	55
28	48	8	56
29	58	3	61
30	63	3	66
	1849	243	2092

APPENDIX A

MESSAGE VOLUME

INCOMING - MAY 1972

DAY	FNWC	NPGS	TOTAL
1	285	51	336
2	303	50	353
3	327	55	382
4	298	46	344
5	310	71	381
6	234	49	283
7	277	33	310
8	303	53	356
9	313	71	384
10	330	58	388
11	284	76	360
12	295	67	362
13	267	41	308
14	287	50	337
15	290	36	326
16	307	39	346
17	329	68	397
18	332	76	408
19	314	53	367
20	301	37	338
21	266	33	299
22	247	36	283
23	327	58	385
24	278	51	329
25	268	65	333
26	282	35	327
27	273	47	320
28	247	19	366
29	229	11	240
30	233	31	264
31	285	54	339
	8921	1520	10441

APPENDIX A

MESSAGE VOLUME

OUTGOING - MAY 1972

DAY	FNWC	NPGS	TOTAL
1	64	7	71
2	63	20	83
3	49	10	59
4	41	18	59
5	49	13	62
6	56	1	57
7	68	0	68
8	56	4	60
9	61	10	71
10	42	15	57
11	35	7	42
12	25	14	39
13	40	5	45
14	41	2	43
15	41	13	54
16	47	9	56
17	42	7	49
18	33	6	39
19	31	10	41
20	49	2	51
21	39	3	42
22	44	8	52
23	40	6	46
24	38	11	49
25	32	10	42
26	29	5	34
27	42	1	43
28	41	1	42
29	41	2	43
30	52	11	63
31	38	9	47
	1369	240	1609

APPENDIX A

MESSAGE VOLUME

INCOMING - JUNE 1972

DAY	FNWC	NPGS	TOTAL
1	282	54	336
2	302	68	370
3	265	43	308
4	261	36	297
5	285	53	338
6	272	56	328
7	299	60	359
8	304	51	355
9	248	47	295
10	250	40	290
11	301	19	320
12	331	49	380
13	309	43	352
14	308	43	351
15	336	44	380
16	306	72	378
17	298	30	328
18	300	18	318
19	248	39	287
20	348	75	423
21	347	66	413
22	365	49	414
23	326	55	381
24	300	34	334
25	323	25	348
26	326	64	390
27	361	63	424
28	389	68	457
29	442	67	509
30	304	58	360
	9326	1489	10815

APPENDIX A

MESSAGE VOLUME

OUTGOING - JUNE 1972

DAY	FNWC	NPGS	TOTAL
1	33	13	46
2	45	20	65
3	46	10	56
4	55	3	58
5	35	16	51
6	49	13	62
7	32	13	45
8	34	14	48
9	28	18	46
10	40	4	44
11	42	2	44
12	44	5	49
13	46	25	71
14	36	22	58
15	34	13	47
16	28	14	42
17	46	8	54
18	40	0	40
19	47	12	59
20	47	12	59
21	31	12	43
22	34	12	46
23	38	16	54
24	47	0	47
25	39	3	42
26	50	9	59
27	49	17	66
28	53	19	72
29	33	13	46
30	42	13	55
	1223	351	1574

APPENDIX A

MESSAGE VOLUME

INCOMING - JULY 1972

DAY	FNWC	NPGS	TOTAL
1	506	91	597
2	488	38	526
3	512	42	554
4	515	42	557
5	530	46	576
6	615	77	692
7	683	83	766
8	661	75	736
9	707	46	753
10	745	50	795
11	805	107	912
12	848	64	912
13	796	123	919
14	738	66	904
15	641	65	706
16	666	38	704
17	690	47	737
18	743	64	807
19	783	95	878
20	776	44	820
21	726	62	788
22	656	53	709
23	659	20	679
24	735	26	761
25	735	40	775
26	711	87	798
27	689	43	732
28	681	63	744
29	589	54	643
30	600	32	632
31	592	34	626
	20801	1813	22729

APPENDIX A

MESSAGE VOLUME

OUTGOING - JULY 1972

DAY	FNWC	NPGS	TOTAL
1	88	5	93
2	84	0	84
3	90	3	93
4	87	7	94
5	77	13	90
6	74	20	94
7	81	23	104
8	94	12	106
9	100	7	107
10	73	21	94
11	77	31	108
12	82	18	100
13	84	30	114
14	88	13	101
15	95	10	105
16	94	7	101
17	78	10	88
18	74	18	92
19	91	18	109
20	94	20	114
21	92	10	102
22	92	8	100
23	83	1	84
24	88	10	98
25	85	28	113
26	67	41	108
27	65	22	87
28	65	9	74
29	70	25	95
30	73	9	82
31	84	11	95
	2569	460	3029

APPENDIX A

MESSAGE VOLUME

INCOMING - AUGUST 1972

DAY	FNWC	NPGS	TOTAL
1	613	42	645
2	690	45	735
3	711	41	752
4	683	47	730
5	644	35	679
6	618	26	644
7	607	28	635
8	694	42	736
9	715	39	754
10	717	39	756
11	673	39	812
12	564	26	590
13	567	20	587
14	563	29	592
15	628	25	653
16	663.	39	702
17	650	44	694
18	572	72	644
19	535	43	678
20	567	32	699
21	545	50	595
22	691	53	744
23	695	74	669
24	667	60	727
25	602	64	666
26	600	59	659
27	603	38	641
28	608	60	668
29	669	62	731
30	631	71	702
31	636	77	713
	19621	1421	21040

APPENDIX A

MESSAGE VOLUME

OUTGOING - AUGUST 1972

DAY	FNWC	NPGS	TOTAL
1	80	16	96
2	58	4	62
3	72	13	85
4	68	14	82
5	83	8	91
6	89	5	94
7	90	17	99
8	88	14	93
9	74	15	91
10	70	9	84
11	82	1	97
12	83	10	92
13	86	15	87
14	86	14	96
15	74	18	89
16	69	14	83
17	67	4	85
18	68	3	82
19	80	9	84
20	90	5	93
21	85	8	93
22	89	11	100
23	67	14	81
24	77	10	87
25	83	8	91
26	84	2	86
27	82	5	87
28	90	21	111
29	79	8	87
30	85	8	93
31	79	16	95
	2457	319	2776

APPENDIX A

MESSAGE VOLUME

INCOMING - SEPTEMBER 1972

DAY	FNWC	NPGS	TOTAL
1	660	72	732
2	679	44	723
3	662	40	702
4	571	67	638
5	554	50	604
6	644	70	714
7	668	65	733
8	694	81	775
9	591	71	662
10	590	51	641
11	601	56	657
12	719	70	789
13	743	71	814
14	736	83	819
15	763	101	864
16	592	61	653
17	577	29	606
18	597	50	647
19	624	84	708
20	619	89	708
21	643	85	728
22	631	85	716
23	646	57	703
24	582	39	621
25	590	63	653
26	667	91	758
27	719	83	802
28	722	86	808
29	666	78	744
30	637	52	689
	19387	2024	21411

APPENDIX A

MESSAGE VOLUME

OUTGOING - SEPTEMBER 1972

DAY	FNWC	NPGS	TOTAL
1	79	10	89
2	80	3	83
3	94	3	97
4	88	7	95
5	89	5	94
6	73	27	100
7	67	17	84
8	93	21	114
9	94	5	99
10	89	6	95
11	93	10	103
12	83	13	96
13	78	11	89
14	82	11	93
15	80	14	94
16	86	15	101
17	87	4	91
18	87	14	101
19	87	16	103
20	79	19	98
21	100	17	117
22	70	6	76
23	62	4	66
24	86	2	88
25	92	19	111
26	103	9	112
27	89	10	99
28	78	8	86
29	86	7	93
30	93	3	96
	2547	316	2863

APPENDIX A

MESSAGE VOLUME

INCOMING - OCTOBER 1972

DAY	FNWC	NPGS	TOTAL
1	690	66	756
2	678	74	752
3	711	81	792
4	707	72	779
5	759	107	866
6	731	84	815
7	682	76	758
8	628	44	672
9	587	42	629
10	572	60	632
11	680	77	757
12	702	80	782
13	708	92	794
14	643	84	735
15	589	85	673
16	689	113	774
17	727	131	840
18	775	118	906
19	840	108	958
20	736	86	844
21	686	83	769
22	675	72	747
23	731	73	804
24	702	96	798
25	788	158	946
26	783	154	937
27	797	161	958
28	661	96	757
29	625	114	739
30	581	110	691
31	713	133	846
	24506	3282	27540

APPENDIX A

MESSAGE VOLUME

OUTGOING - OCTOBER 1972

DAY	FNWC	NPGS	TOTAL
1	102	2	104
2	93	6	99
3	109	5	114
4	88	4	92
5	94	11	105
6	87	5	92
7	95	8	103
8	77	3	80
9	88	7	95
10	95	3	98
11	77	5	82
12	95	2	97
13	79	6	85
14	96	1	97
15	96	4	100
16	109	4	113
17	98	2	100
18	85	2	87
19	92	10	102
20	97	6	103
21	104	2	106
22	96	1	97
23	93	0	93
24	111	3	114
25	85	4	89
26	86	0	86
27	93	8	101
28	91	2	93
29	95	5	100
30	82	1	83
31	123	2	125
	2910	124	3034

APPENDIX A

Appendix B

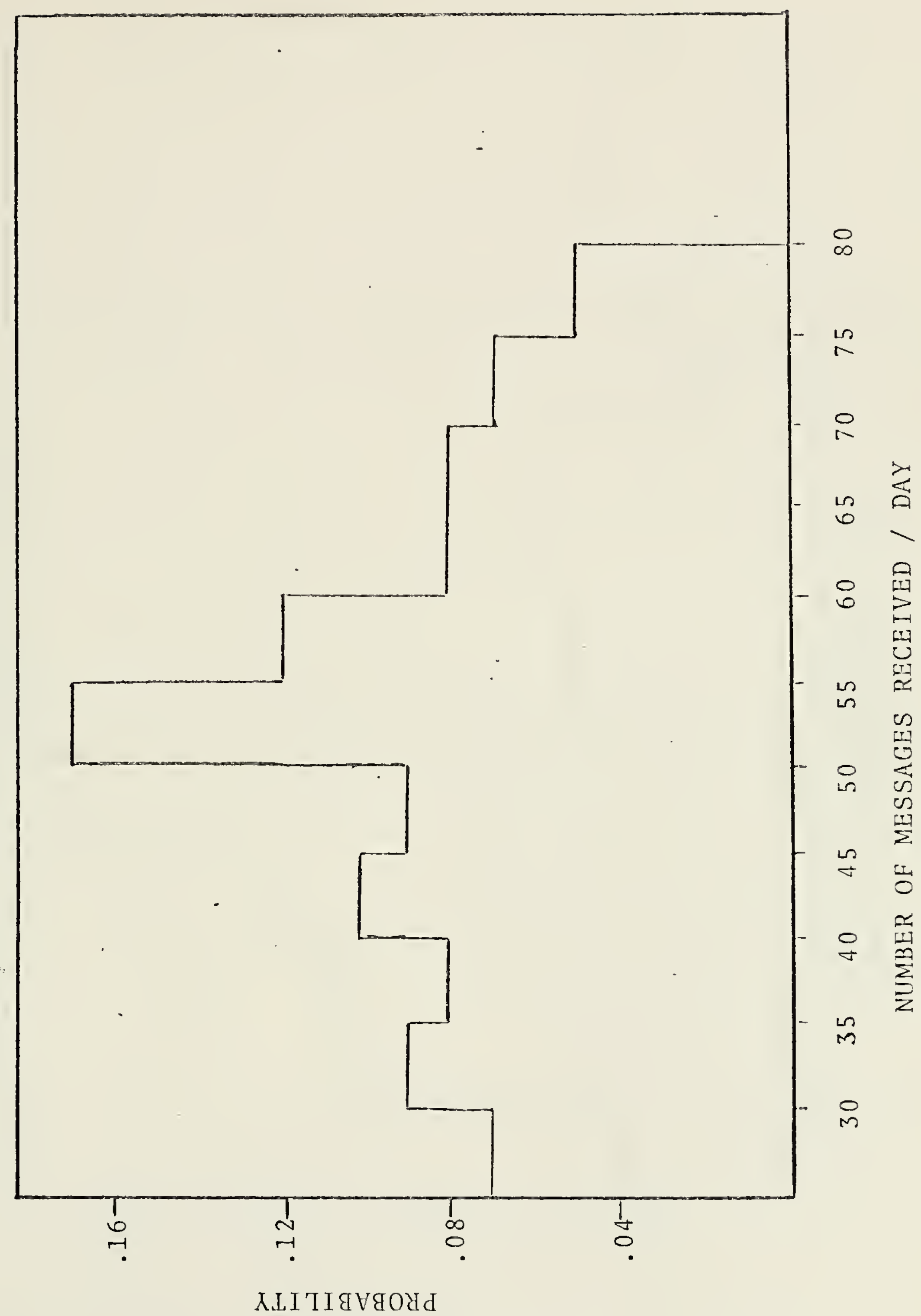

INCOMING FNWC PROBABILITY MASS FUNCTION (APRIL - JUNE 1972)
PROBABILITY
.40
.30
.20
.10
230
250
270
290
310
330
350
370
MESSAGES RECEIVED / DAY

Appendix B

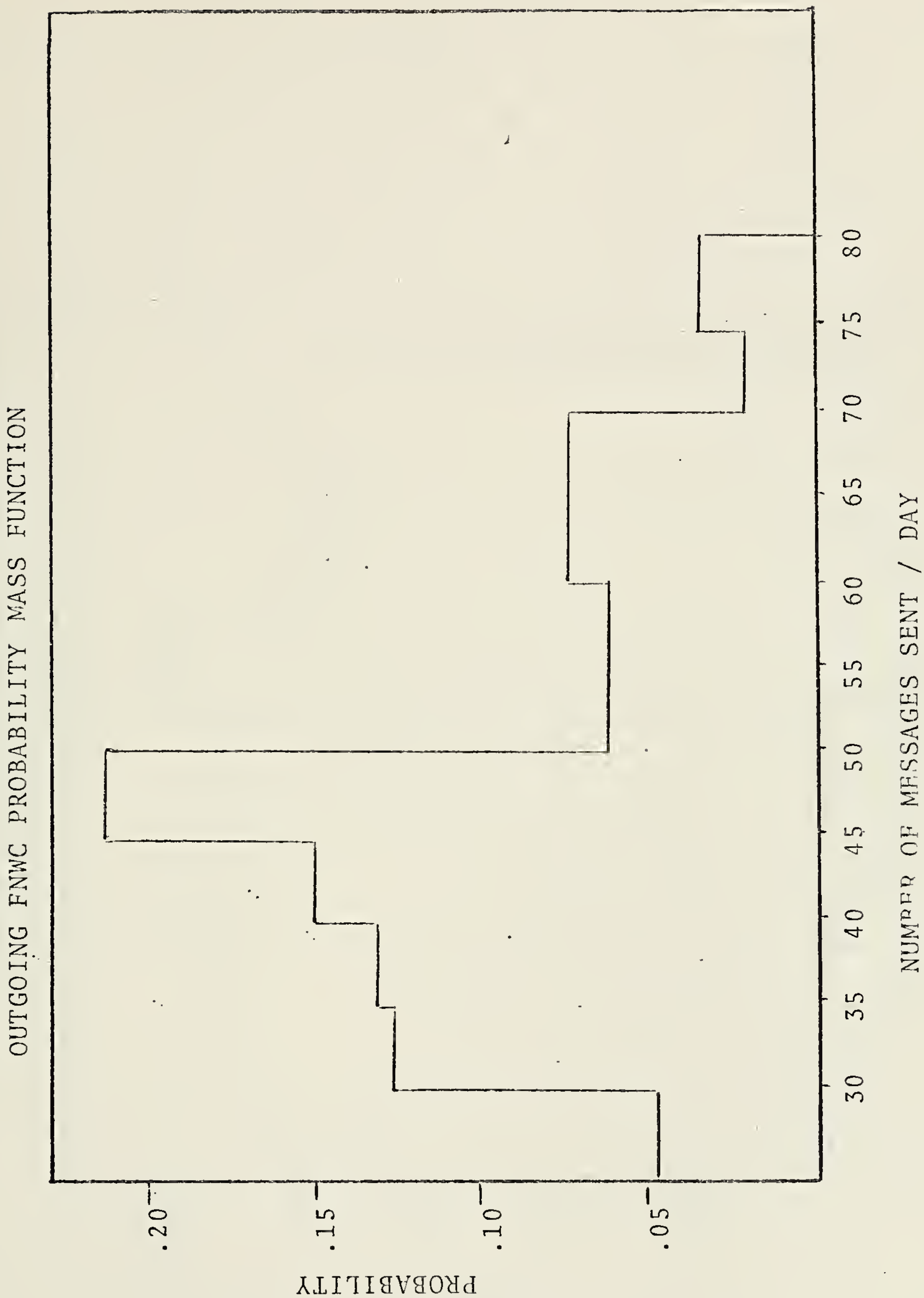
INCOMING FNWC PROBABILITY MASS FUNCTION (JULY - OCTOBER 1972)
PROBABILITY
.20
.15
.10
.05
600
625
650
675
700
725
750
775
800
NUMBER OF MESSAGES RECEIVED / DAY

Appendix B

INCOMING NPGS PROBABILITY MASS FUNCTION

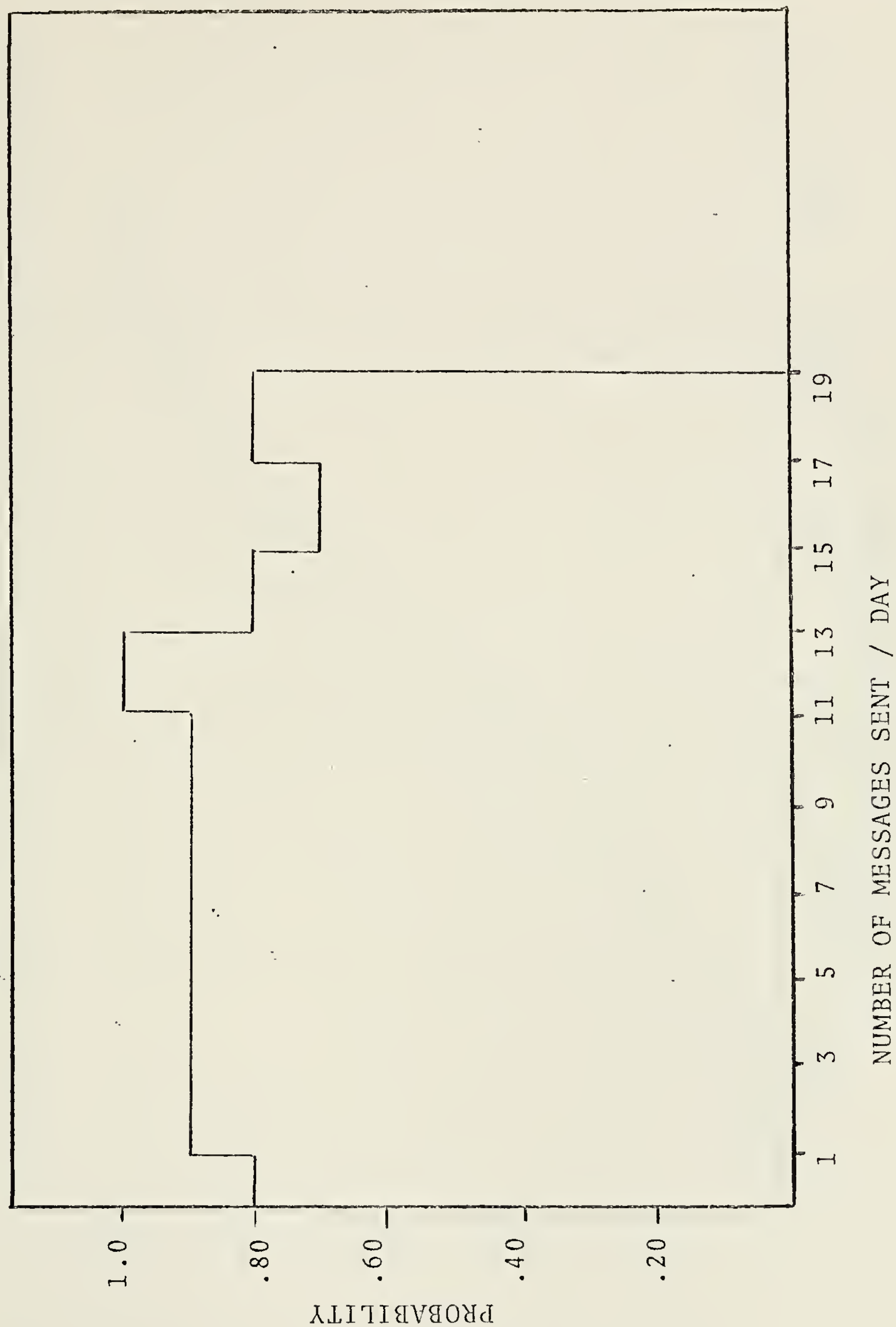


Appendix B


OUTGOING FNWC PROBABILITY MASS FUNCTION
PROBABILITY
.20
.15
.10
.05
30
35
40
45
50
55
60
65
70
75
80
NUMBER OF MESSAGES SENT / DAY

Appendix B

OUTGOING NPGS PROBABILITY MASS FUNCTION

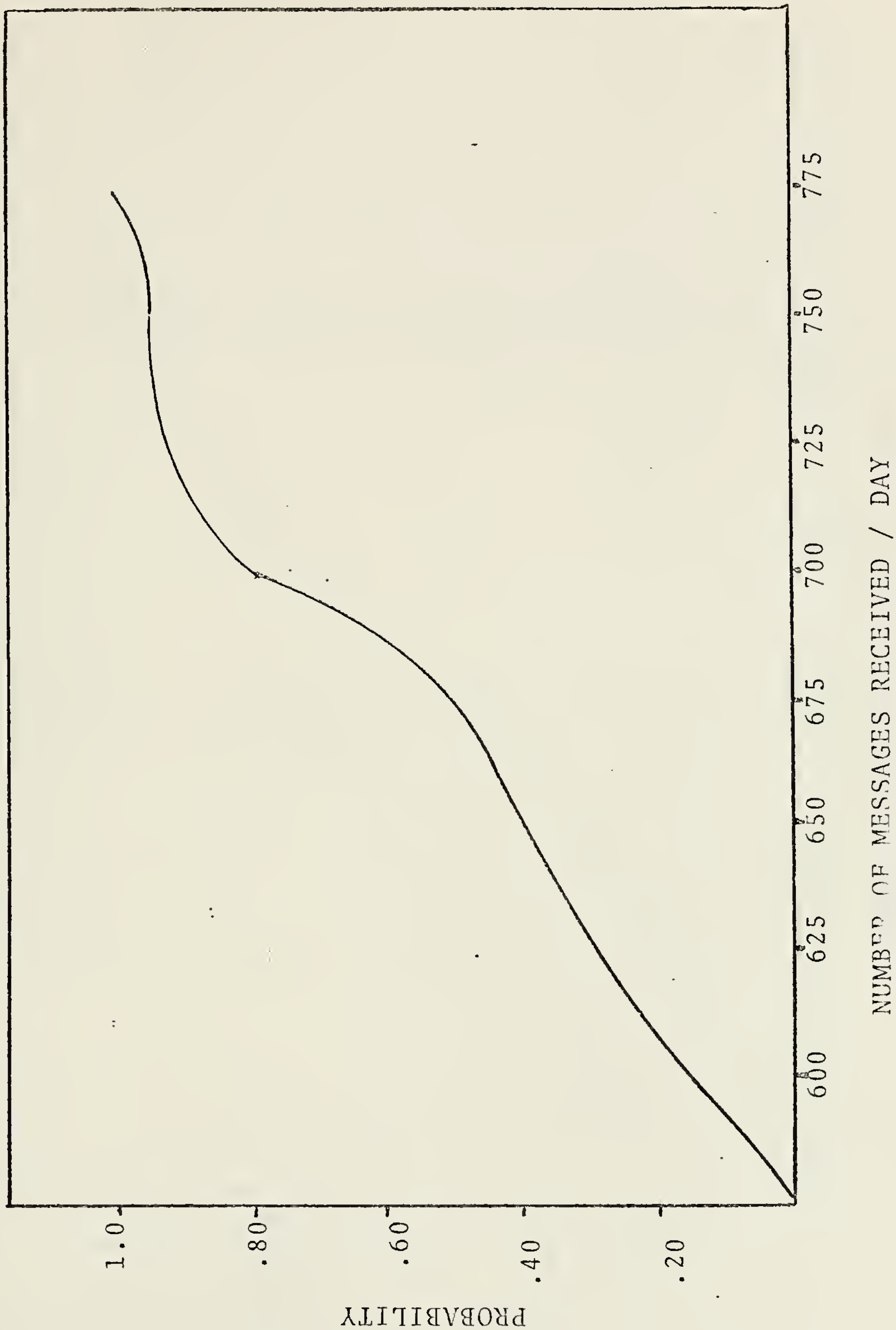


Appendix C

FNWC INCOMING - CUMULATIVE DISTRIBUTION FUNCTION

(APRIL - JUNE 1972)

Appendix C

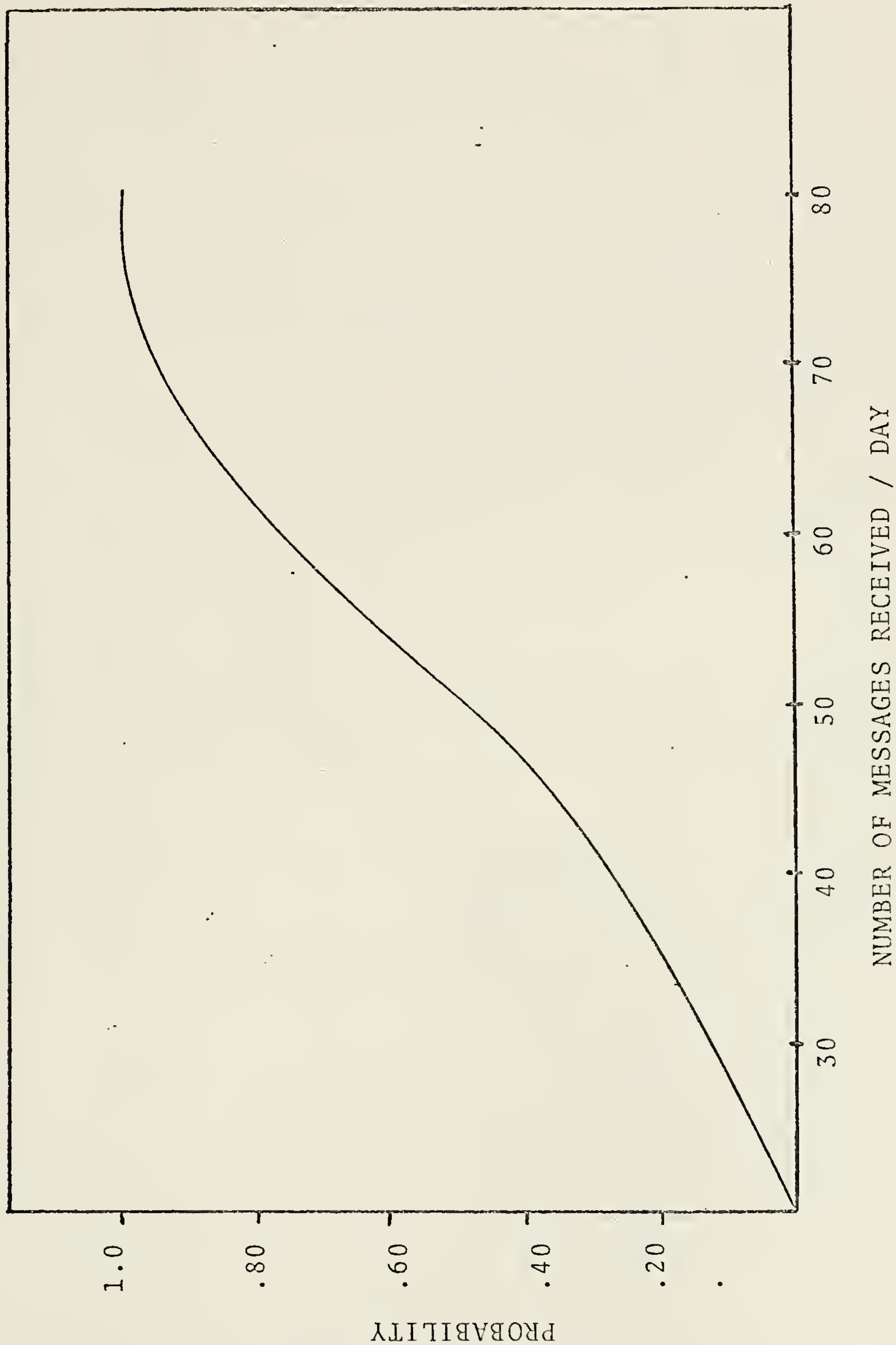


FNWC INCOMING - CUMULATIVE DISTRIBUTION FUNCTION

(JULY - OCTOBER 1972)

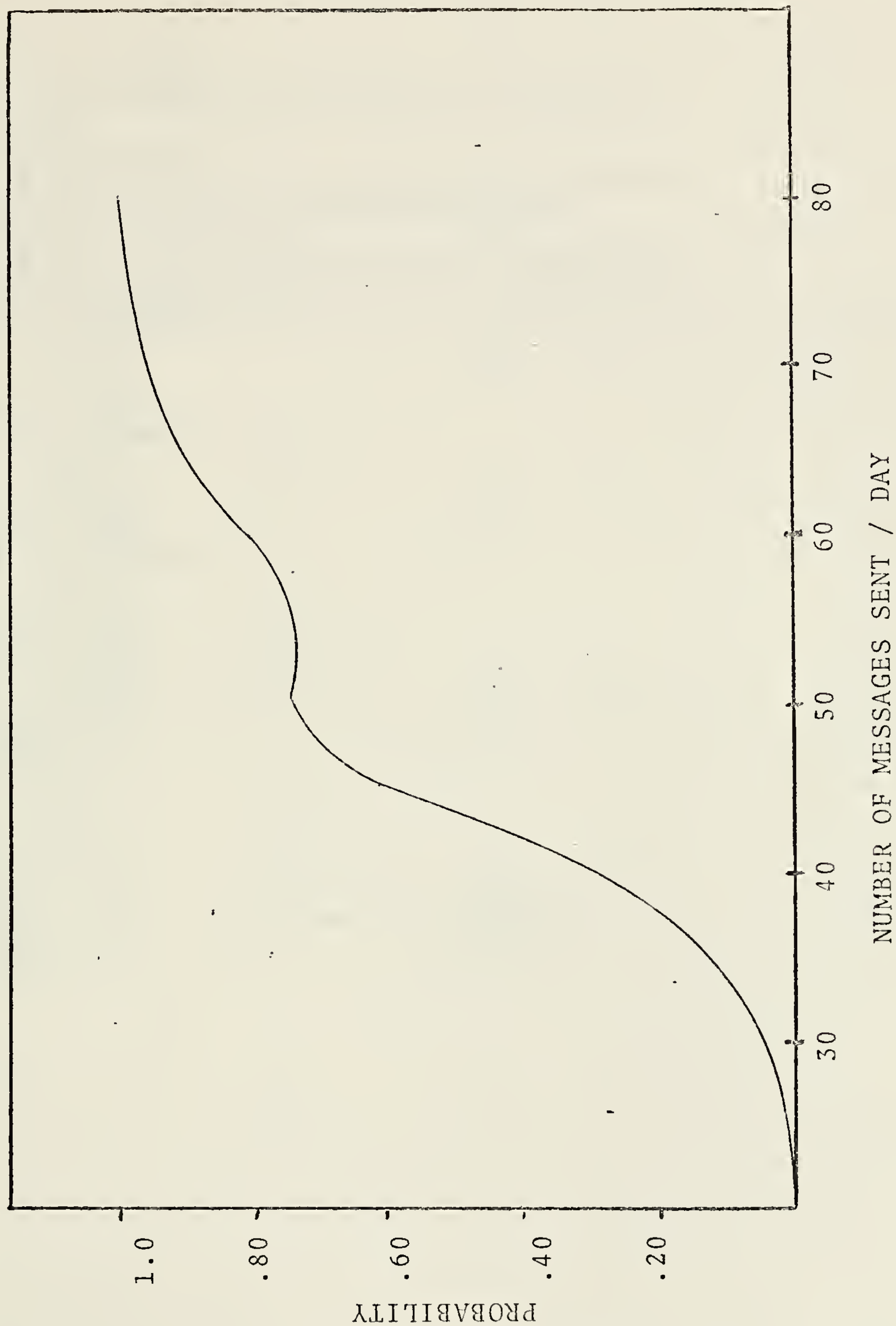
Appendix C

NPGS INCOMING - CUMULATIVE DISTRIBUTION FUNCTION



Appendix C

FNWC OUTGOING - CUMULATIVE DISTRIBUTION FUNCTION



APPENDIX D

THE BASIC GPSS PROGRAM FOR ONE MONTH

```
FNWIN FUNCTION   RN1,C8
0,0/.05,6.00/.17,5.538/.35,5.143/.67,4.80/.87,4.5/.93,
4.235/1.0,4.0
NPGIN FUNCTION   RN1,C11
0,0/.11,48.0/.22,41.143/.28,36.0/.375,32.0/.47,28.8/.64,
26.182/.76,24.0/.84,22.154/.92,20.571/1.0,19.20
FNOUT FUNCTION   RN1,C12
0,0/.05,48.0/.17,41.143/.30,36.0/.45,32.0/.66,28.8/.72,
26.18/.79,24.0/.86,22.154/.95,20.571/.97,19.20/1.0,18.0
GENERATE     1,FN$FNWIN
ASSIGN       1,K1
ASSIGN       2,K3
TRANSFER     ,NEXT
GENERATE     1,FN$NPGIN
ASSIGN       1,K2
ASSIGN       2,K3
TRANSFER     ,NEXT
GENERATE     1,FN$FNOUT
ASSIGN       1,K3
ASSIGN       2,K3
TRANSFER     ,NEXT
GENERATE     160,160
ASSIGN       1,K4
ASSIGN       2,K8
NEXT  QUEUE   1
SEIZE        1
DEPART       1
ADVANCE      P2,2
RELEASE      1
TERMINATE
GENERATE     43200          (One month in minutes)
TERMINATE    1
START        1
END
```

APPENDIX E

THE RESULTS OF THE BASIC PROGRAM RUN FOR ONE MONTH UNDER THE NORMAL LOAD PRIOR TO JULY , 1972

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN
1	.950	13171	3.118

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	23	2.959	13171	1793	13.6	9,706

APPENDIX F

RESULTS OF THE BASIC PROGRAM RUN FOR

THREE MONTHS (APRIL, MAY AND JUNE 1972)

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.942	39418	3.099	6

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	23	2.463	39424	6324	16.0	8.093

APPENDIX G

FNWC INCOMING AVERAGE PROCESSING

TIME REDUCED BY ONE MINUTE

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.718	13139	2.362	2

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	7	.591	13140	6764	51.4	1.944

APPENDIX H

RESULTS OF INCREASING FNWC INCOMING PROCESSING TIME BY ONE MINUTE

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.996	598	3.872	19

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	107	57.690	705	8	1.1	190.09

APPENDIX I

NPGS INCOMING AVERAGE PROCESSING

TIME REDUCED BY ONE MINUTE

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.908	13131	2.988	8

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	12	1.549	13131	3186	24.2	5.096

APPENDIX J

BASIC PROGRAM RUN FOR ONE MONTH --

ALL AVERAGE PROCESSING TIMES REDUCED BY ONE MINUTE

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.639	13155	2.099	12

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	6	.330	13155	8426	64.0	1.085

APPENDIX K

NEW MESSAGE LOAD REFLECTING DOUBLING OF FNWC

INCOMING IN JULY 1972 - NO REDUCTION IN

HANDLING TIMES

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.996	93	3.247	41

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	106	49.603	199	1	.5	75.527

APPENDIX L

INCREASED LOAD IS EASILY HANDLED BY MEANS OF THE REDUCTION IN PROCESSING TIMES IN SEPTEMBER 1972

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.
1	.781	28816	1.171	11

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS
1	12	.962	28817	16219	56.2	1.443

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ABSTRACT

A management analysis of the Naval Telecommunications, Center, Monterey, was conducted to analyze the requirements placed on this center, as well as to determine how capable it was to perform these requirements. A computer simulation model was developed and used to quantify the message processing capabilities of the center under various historical conditions. Results showed that the various requirements placed on this center have been constantly increasing, without regard to the center's ability to handle them. The results also showed that at times the center's capabilities were limited by its machine capabilities, while at other times they were limited by the center's own internal message handling procedures.

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SIMULATION						

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